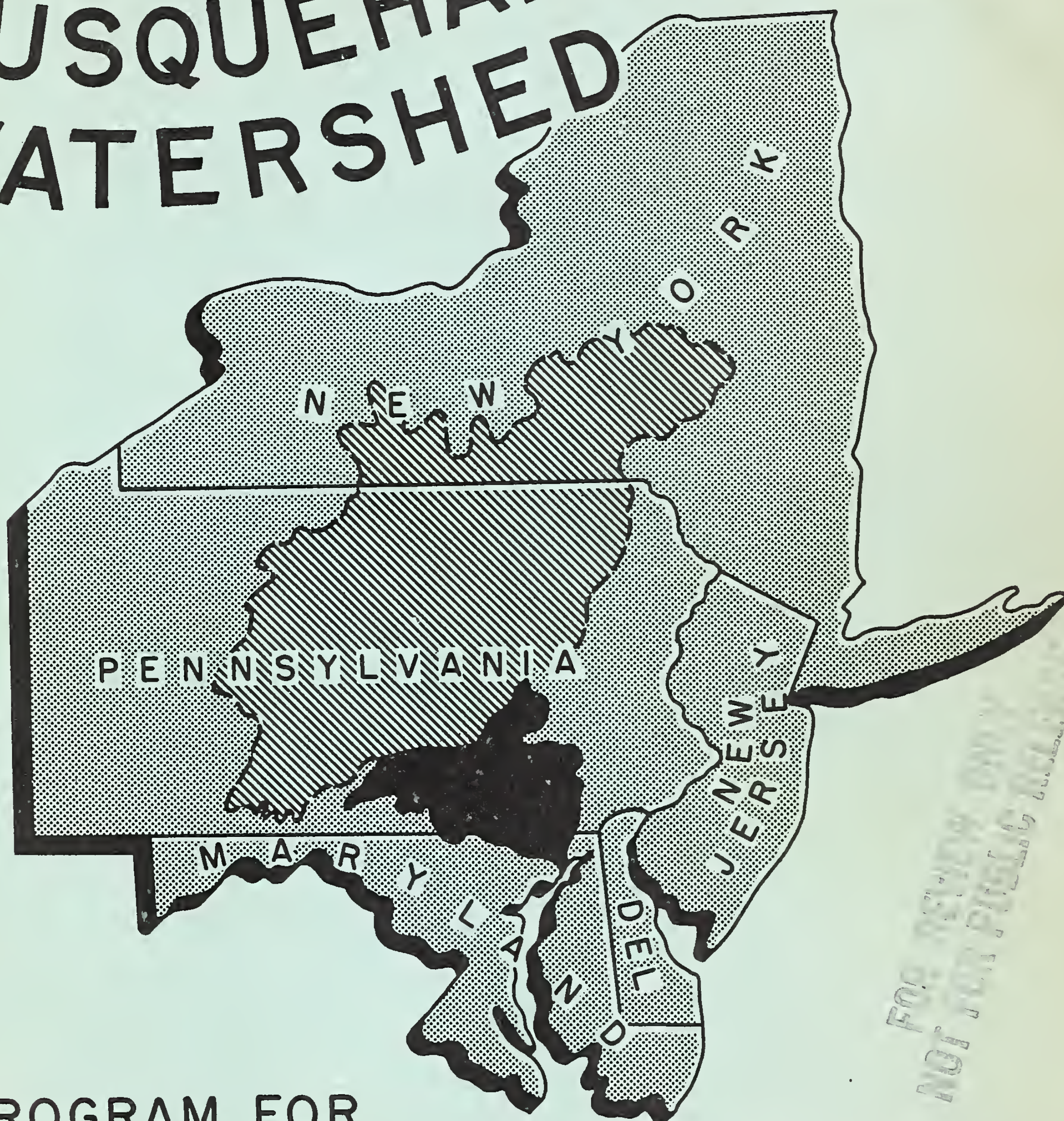
SURVEY REPORT

LOWER SUSQUEHANNA RIVER WATERSHED



PROGRAM FOR
RUNOFF AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION

U. S. DEPARTMENT OF AGRICULTURE

0002

MAY, 1952

V,C,3

UNITED STATES DEPARTMENT OF AGRICULTURE

LOWER SUSQUEHANNA RIVER WATERSHED

Pennsylvania and Maryland, +3a

Program for Runoff and Waterflow Retardation and
Soil-Erosion Prevention

Pursuant to the Act Approved June 22, 1936 (49 Stat. 1570)
as Amended and Supplemented

CONTENTS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR

MAY, 1952

AGR-SCS-UPPER DARBY, PA.

INTRODUCTION

Authority - This report is submitted under the provisions of the Act approved June 22, 1936 (49 Stat. 1570), as amended and supplemented.

Purpose and Scope of Report - The purpose of this report is to outline a program for runoff and waterflow retardation and soil-erosion prevention for the Lower Susquehanna River Watershed in Pennsylvania and Maryland; and to present recommendations for installing and maintaining the program, together with an analysis of the costs and benefits.

RECOMMENDATIONS

It is recommended that a program for runoff and waterflow retardation and soil-erosion prevention be installed in the Lower Susquehanna River Watershed in Pennsylvania and Maryland during a 20-year period at an estimated cost of $6,285,000 to the Federal Government, and at an estimated cost of $5,332,000 or its equivalent 1/ to local interests, making an estimated total cost of $11,617,000 2/.

The recommended program will be operated and maintained at an estimated annual cost of $14,000 to the Federal Government, and $1,116,000 or its equivalent to local interests, making an estimated total annual cost of $1,130,000.

1/ Labor, materials, equipment, land, easements, rights-of-way, and other contributions in lieu of cash payments.
2/ Based on projected long term prices.

It is estimated that the recommended program will yield an average annual benefit of $6,444,700 based on projected long term prices. The ratio of the average annual benefit to the average annual cost is 3.74 to 1.

The program herein recommended includes the intensification, acceleration, and adaptation of certain activities under current programs of the Department of Agriculture, and additional measures not now regularly carried out in such programs, all of which are necessary to complete a balanced runoff and waterflow retardation and erosion control program for the watershed. It is recommended that the Secretary of Agriculture be authorized to carry out this program. Although the current activities of the Department primarily related to the Flood Control Act are not included in the program herein specifically recommended, this program is based on the continuation of such current activities at least at their present level.

The recommended program includes certain adjustments in land use in accordance with the needs and capabilities of the land and the following practices and measures: contour strip cropping, diversions and terraces, establishing perennial hay, outlets and waterways, pasture management, contour furrowing, streambank erosion control, erosion control structures, wildlife area development, improved forest management, forest planting, public land acquisition, diking, and stream channel improvement.

Technical services will be made available for planning and applying the necessary land use adjustments, for planning and applying conservation measures on the watershed, and for integrating

the measures included in the recommended program. Educational assistance, to facilitate the establishment of measures on a subwatershed basis, will be provided as a part of the recommended program.

The Secretary of Agriculture may make such modifications or substitutions of the measures described herein as may be deemed advisable due to changed physical or economic conditions or improved techniques whenever he determines that such action will be in furtherance of the objectives of the recommended program.

The authority of the Secretary of Agriculture to prosecute the recommended program shall be supplemental to all other authority vested in him, and nothing in this report shall be construed to limit the exercise of powers heretofore or hereafter conferred on him by law to carry out any of the measures described herein or any other measures that are similar or related to the measures described herein.

The Secretary of Agriculture may construct such buildings and other improvements as are needed to carry out the measures included in the recommended program.

DESCRIPTION OF WATERSHED

The Lower Susquehanna River Watershed discussed in this report comprises that portion of the total basin from Harrisburg, Pennsylvania on the main river to its mouth on Chesapeake Bay. The
2,524,160
drainage area in this segment is 3,944 square miles with about
2,347,469. 176,691
93 percent in Pennsylvania and 7 percent in Maryland. The area is about 100 miles from east to west and 70 miles from north to south

at the extreme dimensions. Ninety-five miles of the main stream and seven major tributaries are included in this portion of the main basin. Swatara, Conestoga, and Octoraro Creeks enter from the eastern side of the watershed, while Yellow Breeches, Conodoquinet, West Conewago, and Codorus Creeks enter from the west. The drainage areas of these tributaries range in size from 210 to 570 square miles.

The watershed area is entirely included in two physiographic provinces, the Appalachian Valley and Ridge Province and the Piedmont Plateau.

The Valley and Ridge portion in the northern part of the watershed is characterized by mountainous ridges alternated with wide limestone valleys. Soils, developed on shales and sandstones, occur on the upland areas. Gully and sheet erosion are moderately severe and runoff is fairly rapid. Limestone soils occur in the valleys between the shale and sandstone ridges. These soils are deep, medium textured, and well drained. Fertility is high and the area is well known for its agricultural production. Gully and sheet erosion are severe where long slopes are used for intensive tillage.

The Piedmont Plateau section in the southern part of the watershed is generally rolling to hilly. Soil development has taken place on a wide variety of rocks including gneisses, schists and quartzites as well as shales and sandstones. The soils are generally deep, medium textured and have good infiltration rates. Soil erosion ranges from moderate to severe, since most of the farming is on rolling topography.

The total annual precipitation ranges from 38 to 45 inches. This is distributed almost evenly throughout the year, with no month or season showing a marked excess over the others.

About 66 percent of the area is openland, 27 percent is forest land, and the remaining 7 percent is urban, roads, and water. Of the openland 1,533,500 acres are in farms and 128,600 acres in non-farm ownership. Of the forest land 216,000 acres are in farms, 381,200 in non-farm private ownership, and 88,200 acres in public ownership. There are approximately 25,200 farms in the watershed.

The population of the watershed in 1950 was estimated at 798,000. The largest cities are Harrisburg, Lancaster, and York, all in Pennsylvania. Transportation facilities are excellent and industry is well developed. Major industries include steel, limestone quarrying and processing, insulation, farm equipment, paper and wood fibre.

Agriculture is highly developed with excellent markets. Livestock and poultry production, dairying, vegetable crops, tobacco culture and production of apples and peaches are the main farm enterprises. Most farms are owner-operated and, generally, agricultural production is high. Lancaster County, in the limestone section of the watershed, is among the first ten counties in the United States in value of total production.

FLOOD, SEDIMENT, AND EROSION PROBLEMS

Major flood damages have occurred on the main stem of the Susquehanna River but hydrologic investigations indicate that no significant reduction in flood crests could be claimed as a result

of the remedial program on the Lower Susquehanna River Watershed, so these damages were not evaluated.

Flood damages on the major and minor tributaries of the watershed are of frequent occurrence. On some of the small tributaries, losses are an annual occurrence. Floods usually occur in the spring and early summer, and the losses sustained are mainly to highways, growing crops and pasture.

Severe localized floods, such as occurred in September 1950 on Deer Creek and in September 1951 on Quittapahilla Creek, are usually caused by intense local storms that do not create flood flows on the major tributaries.

Heavy storms of several days' duration, covering the entire watershed area, cause the greatest amount of damage. The floods of September 1933, March 1936, and May 1942 are typical of this type.

Other damages caused by floods, while not evaluated in monetary terms in this report, include loss of life, illness, insecurity of property and income, disruption of public services, and disturbance of the normal economic and social activity of the population.

Damages caused by sedimentation occur mainly as increased maintenance costs for highways; decreased agricultural production on the bottomland of some of the small tributaries; and increased water treatment costs. Highway maintenance costs are affected by sediment deposition in culverts, ditches, under highway bridges, and on the highway surface. The impairment of highway drainage systems frequently results in washouts and other damages to highways. Sedimentation damage is greatest when storms occur during

the early growing season when there is insufficient protective cover. Deposits of sediment in low gradient stream channels also contribute to flood damage by reducing the capacity of these channels.

Soil erosion in the Lower Susquehanna River Watershed, in addition to causing sediment damages, seriously affects land productivity and crop production costs. Based on the present rate of soil erosion, the annual loss from reduced yields and increased production costs necessary to prevent yield declines is an estimated $2,031,900.

Other damages resulting from erosion and sediment, but not evaluated in monetary terms in this report, include reduced aquatic life in streams, reduced ability of streams to assimilate discharges of municipal and industrial pollution, and the adverse effect on recreational values.

Average annual damages are shown in table 1. These damages do not include those which will be prevented by current or authorized programs of public agencies.

Table 1. Estimated Average Annual Monetary Damage 1/
Lower Susquehanna River Watershed

Type of Damage	Average Annual Damage	
	(dollars)	
Damage Due to Inundation		
Agricultural	27,300	
Non-Agricultural	196,500	
Subtotal		223,800
Damage Due to Sediment		
Channel Sedimentation	43,100	
Highway Sedimentation	64,000	
Water Supply Pollution	7,700	
Reservoir Sedimentation	10,000	
Subtotal		124,800
Damage Due to Erosion		2,031,900
TOTAL AVERAGE ANNUAL DAMAGE		2,380,500

1/ Based on projected long term prices.

ACTIVITIES RELATED TO FLOOD CONTROL

The Department of Agriculture is actively cooperating with state and local agencies in carrying out programs for the conservation of soil, water, and timber resources in the watershed.

The Forest Service cooperates with state forestry agencies in providing protection from forest fire, in making tree seedlings available for reforestation, and in providing technical services to assist owners in proper management of forest lands. In recent years the state fire protection organizations have provided protection that is considered adequate for flood control purposes.

The Production and Marketing Administration, with its Agricultural Conservation Program of direct aids, offers financial assistance to farmers for carrying out soil and water conservation practices.

The Department also cooperates with State Extension Services and Experiment Stations in educational and research work in the conservation of soil and water resources.

The Soil Conservation Service is assisting soil conservation districts in the application of soil and water conservation practices and measures on farm lands.

Although the primary purpose of these conservation programs in this watershed has been the maintenance of soil resources and improvement of crop and timber yields, they have produced some flood control benefits.

The present annual Federal cost of those portions of the Department's "going" programs which produce some flood control and associated benefits is approximately $414,200.

Flood control works of improvement on Codorus Creek, consisting of the Indian Rock Dam, and improvements to Codorus Creek Channel have been installed by the Department of the Army, Corps of Engineers. This project was authorized by the Flood Control Act approved June 22, 1936, as amended and supplemented. Indian Rock Dam is located on the main branch of Codorus Creek about 3 miles above York, Pennsylvania. The reservoir will control the entire drainage area of the main branch and 41 percent of the drainage area above York. The improvements to Codorus Creek channel are in the vicinity of and through the city of York and will provide

protection to the city against a flood discharge approximately 33 percent greater than the maximum flood of record. The program herein recommended will supplement these improvements in further alleviating flood damages on the Codorus Creek Watershed.

Soil conservation districts have been organized under state laws in all counties of the watershed with the exception of Schuylkill, Dauphin, and Cumberland Counties in Pennsylvania. A program of soil and water conservation and land management on farm lands is being developed by these districts.

Almost 11 percent of the forest land is in the form of public forests, parks, and game lands and is administered by state or other public agencies. Approximately one percent is under Federal ownership as part of the Indiantown Gap Military Reservation. In general, both present management and protection from fire and grazing on these areas are satisfactory for water retardation purposes.

The city of York has under construction flood control works of improvement consisting of channel improvement and diking on a tributary of Codorus Creek.

The benefits of the program herein recommended do not include any of the benefits accruing as a result of these related activities.

RECOMMENDED PROGRAM

The recommended program for runoff and waterflow retardation and soil-erosion prevention includes certain land use adjustments in accordance with the needs and capabilities of the land and the following practices and measures:

Contour Strip Cropping

The practice of growing hay or close growing and soil conserving crops in contour strips, alternating with clean tilled or soil depleting crops, will be applied on approximately 566,700 acres of cropland. Contour tillage operations in conjunction with contour strip cropping will provide appreciable surface detention storage for runoff. Such a system will, in addition, keep at least half the sloping cropland in erosion resisting crops at all times, lessen the amount and velocity of runoff and the concentration of water in gullies or channels, thereby reducing flood peaks and soil losses by erosion.

Diversions and Terraces

Approximately 2,600 miles of diversions and terraces will be installed to provide for intercepting surface runoff from sloping land and carry it in properly designed and constructed channels across the slopes to an outlet or waterway. Terraces will be installed on the more moderately sloping lands with short rotations. Diversions will be installed on the steeper slopes and in conjunction with less intensive rotations. The installation of these measures will furnish protection from damaging runoff to the lands lying immediately below and will significantly reduce erosion and sediment production.

Establishing Perennial Hay

Approximately 30,800 acres of perennial grasses and legumes will be established to protect land not suitable for row crops and to protect such measures as diversions, and outlets and waterways. The success of this measure depends on the quality of the stand secured. Proper fertilization, therefore, is a definite part of the measure designed to secure an erosion-resisting crop. This measure, by increasing the infiltration rate, will reduce runoff and flood damage and, by protecting other measures, will reduce damaging gully erosion and resulting sedimentation.

Outlets and Waterways

Adequate systems for the disposal of runoff water are a necessary part of the program to reduce floodwater and sediment damage. Approximately 2,300 acres of outlets and waterways will be established to provide for the safe disposal of runoff from terrace and diversion systems. This will result in reduced gully erosion and sediment production. The outlets and waterways will be vegetated and will include broad meadow strips and constructed channels. Supporting structures, required as a part of the disposal system, are described in another paragraph.

Pasture Management

Pasture management, consisting of mowing to remove weeds and mature grasses, the scattering of droppings, and the control of grazing intensity, will be applied on

approximately 109,600 acres of pasture so that the improved vegetative cover will increase infiltration and reduce runoff. Fences will be used to facilitate the control of grazing intensity. Brush or other obstructions to mowing will be removed where feasible.

Contour Furrows

Level furrows or small level terraces will be installed on approximately 6,000 acres of pasture land. The furrows will be spaced and constructed so that approximately one-half inch of runoff will be held in detention storage. In addition to reducing runoff, the installation of this measure will control erosion on sediment source areas.

Streambank Erosion Control

Approximately 65 miles of eroding streambanks along minor tributaries will be controlled by the use of riprap and shrub plantings. Livestock will be excluded by either wire or multiflora rose fence. The establishment of this measure will halt the destruction of fertile bottomlands and will reduce the quantity of sediment getting into the streams.

Erosion Control Structures

Approximately 6,900 erosion control structures, including small check dams, gully structures, and culverts, 9 will be installed as part of the water disposal system or for gully stabilization. Concentration of runoff requires special erosion control structures to protect the channels or natural drainageways from gullying and to furnish

protection to railroad and highway ditches. New and larger culverts will be necessary to discharge runoff safely under railroad and highway fills. The establishment of this measure will reduce the rate of gully erosion in existing drainageways and permit the installation of adequate water disposal systems which will materially reduce sheet and gully erosion on the fields protected.

Wildlife Area Development

Small, irregular and inaccessible areas, as well as narrow strips of land along field borders often left idle, are serious erosion problems and are usually runoff and sediment sources. Approximately 35,400 acres will be stabilized by planting and protection. The stabilization of these areas will reduce erosion and sediment production and provide wildlife cover.

Improved Forest Management

Management activities will be intensified on all forest land in the watershed for the primary purpose of improving its hydrologic condition. Under these improved conditions, infiltration rates will be higher, detention capacity will be increased, and the area of occurrence of impermeably frozen soils will be reduced. These changes will result in reducing both soil erosion and the production of excess runoff and sediment from forest lands.

In addition to bettering hydrologic conditions, improved management of forest lands will increase the growth

and stocking and will ultimately provide higher and more sustained income from these lands. Such returns will eventually be more than sufficient to offset the costs to the participating forest land owners.

The program will consist of assistance, instruction and demonstration in planning and applying good management practices, where needed, on the forest land area of 721,800 acres. Items which will be included are: assistance in the development of plans outlining the steps necessary to operate forest lands efficiently and economically while integrating watershed management and timber production objectives; assistance in the selection of trees to be harvested to improve both the condition of the residual stand and the quality of the marketable products; advice and assistance on logging methods which cause the least distrubance to forest soils and drainageways, including the proper installation of logging roads and skid trails; advice and assistance in correcting unsatisfactory conditions on existing roads and trails which, because of poor location and inadequate drainage, are sources of aggravated runoff and sedimentation; assistance in protecting forest areas from livestock grazing which reduces the organic matter and compacts the soil of forest lands, thereby reducing seriously their infiltration and water-holding capacity.

Although improved management is needed in some degree on the entire forest area, not all of the measures discussed

above will be needed on every acre. The following approximate amounts are recommended:

Management plans	420,000 acres
Timber marking	310,000 "
Utilization service	640,000 "
Logging road stabilization	500,000 "
Protection from grazing	12,000 "

Forest Planting

The program of land use adjustments includes the conversion of 52,800 acres of openland to forest land by tree planting or natural reseeding. Approximately 26,900 acres, which are not expected to restock naturally within a reasonable length of time, will be planted to trees. Establishment of a forest cover on these lands will increase infiltration rates, enlarge soil moisture storage capacity, and reduce the present rate of sediment production. Approximately 21,900 acres of private land and about 5,000 acres of land to be acquired by public agencies will be planted.

Public Land Acquisition

Approximately 5,000 acres of flood source areas in the headwaters will be placed in public ownership. These formerly well forested areas have been so abused that they need major rehabilitation to restore the watershed cover for effective runoff and sediment control. Because of low productivity and the low returns to be expected from this land for many years, proper management for either watershed

protection or timber production is not an attractive investment for private capital. Public ownership is an essential first step for insuring the installation of rehabilitational measures and providing the necessary continuity of management. The land will be acquired through voluntary sales in accordance with existing state policy.

Diking

One and seven-tenths miles of diking will be constructed to provide protection from inundation to valuable bottomland and to such improvements as highways and farm buildings where limitation of rights-of-ways and gradients prohibit the use of channel improvement. Floodways will be provided to safely carry flood discharges of design frequency.

Stream Channel Improvement

Approximately 104 miles of stream channel will be improved to reduce the damages resulting from inundation of valuable bottomland, furnish flood protection for high-value improvements, such as farm buildings, and provide outlets for drainage works. The discharge capacity of stream channels will be increased by the removal of debris and sediment deposits, clearing and snagging, realignment and bank sloping.

Landowners and operators and others in the watershed will be furnished educational assistance relative to the need for the recommended program and its purposes and objectives. Information will

be supplied as to the manner in which landowners and operators now obtain services and assistance that are available through the various governmental agencies, and how they can and should, by their own efforts, contribute successfully and most economically to the accomplishment of the over-all objectives. Intensified educational efforts will be directed to familiarizing farmers with the specific practices and measures essential to runoff and waterflow retardation and soil-erosion prevention, how to install those measures not requiring the detailed assistance of a specialized technician, how to maintain them, and how to integrate them into the soundest farming system to produce the greatest benefit over a long period of time.

The Department is committed to a watershed and subwatershed approach in carrying out the recommended program. It is essential that educational assistance provided under this program be directed toward furthering the specific objectives of floodwater and sediment damage reduction and that it be fitted as to method and synchronization into subwatershed operations activities.

Technical services will be provided for (1) planning and applying improved forest management practices for watershed protection, (2) planning and applying land use adjustments, (3) planning and applying conservation measures on the farm, and (4) integrating the installation of individual measures into a proper combination to achieve the most effective program of runoff and waterflow retardation and soil-erosion prevention. These services are required to assist the people in the watershed in installing the recommended measures on their land and in adopting the recommended practices for their farm and forest land operations.

The quantities of measures included in the recommended program are based on total watershed needs less the estimated accomplishments under "going" programs over a 20-year period. Reductions in the acreages of clean tilled and small grain crops and acreage increases in managed pasture, perennial hay crops, and farm forest lands will result from the installation of the recommended program.

COST OF RECOMMENDED PROGRAM

The estimated cost of installing the recommended program in the Lower Susquehanna River Watershed is shown in table 2.

The Federal Government will bear approximately 14.8 percent of the total installation cost for technical services, 3.1 percent for educational assistance, 33.3 percent for direct aids, and 2.9 percent for the administration of direct aids. Non-federal public agencies will bear approximately 1.1 percent of the total installation cost for technical services, 3.1 percent for educational assistance, and 2.1 percent for direct aids. Private interests will bear the remaining 39.6 percent of the total installation cost of the recommended program.

Table 2. Estimated Cost of Installing the Recommended Program
Lower Susquehanna River Watershed
(Projected Long Term Prices)

Measure	Unit	Quantity	Total Cost (dollars)
1. Contour Strip Cropping	Acres	566,700	990,000
2. Diversions and Terraces	Miles	2,600	1,041,000
3. Establishing Perennial Hay	Acres	30,800	1,470,000
4. Outlets and Waterways	Acres	2,300	560,000
5. Pasture Management	Acres	109,600	1,695,000
6. Contour Furrows	Acres	6,000	96,000
7. Streambank Erosion Control	Miles	65	795,000
8. Erosion Control Structures	No.	6,900	2,764,000
9. Wildlife Area Development	Acres	35,400	709,000
10. Improved Forest Management	Acres	721,800	613,000
11. Forest Planting	Acres	26,900	489,000
12. Public Land Acquisition	Acres	5,000	26,000
13. Diking	Miles	1.7	28,000
14. Stream Channel Improvement	Miles	104	341,000
TOTAL			11,617,000

The costs of administration of direct aids, technical services, and educational assistance are included in the above costs. Of these amounts, non-federal public agencies will bear one-half the cost of technical services on privately owned forest land.

The estimated average annual cost of operating and maintaining the recommended program is $1,130,000. The Federal Government will bear approximately 1.3 percent of this annual maintenance cost

to provide technical services necessary to assure proper use and conservation and management of lands. State and local governments will bear approximately 1.4 percent of this cost, and private interests will bear the remaining 97.3 percent.

BENEFIT FROM RECOMMENDED PROGRAM

The estimated average annual monetary benefit resulting from the recommended program when it attains maximum effectiveness is shown in table 3.

In addition to the benefits listed in table 3, there are many unevaluated benefits, such as saving of life and alleviating mental distress, improving community organizations and facilities, maintaining and increasing the tax base, improving recreational values, and increasing fish and game production.

COMPARISON OF BENEFIT AND COST

Based on projected long term prices, the ratio of the average annual benefit to the average annual cost of the recommended program is 3.74 to 1.

Table 3. Estimated Average Annual Monetary Benefit
From the Recommended Program
Lower Susquehanna River Watershed

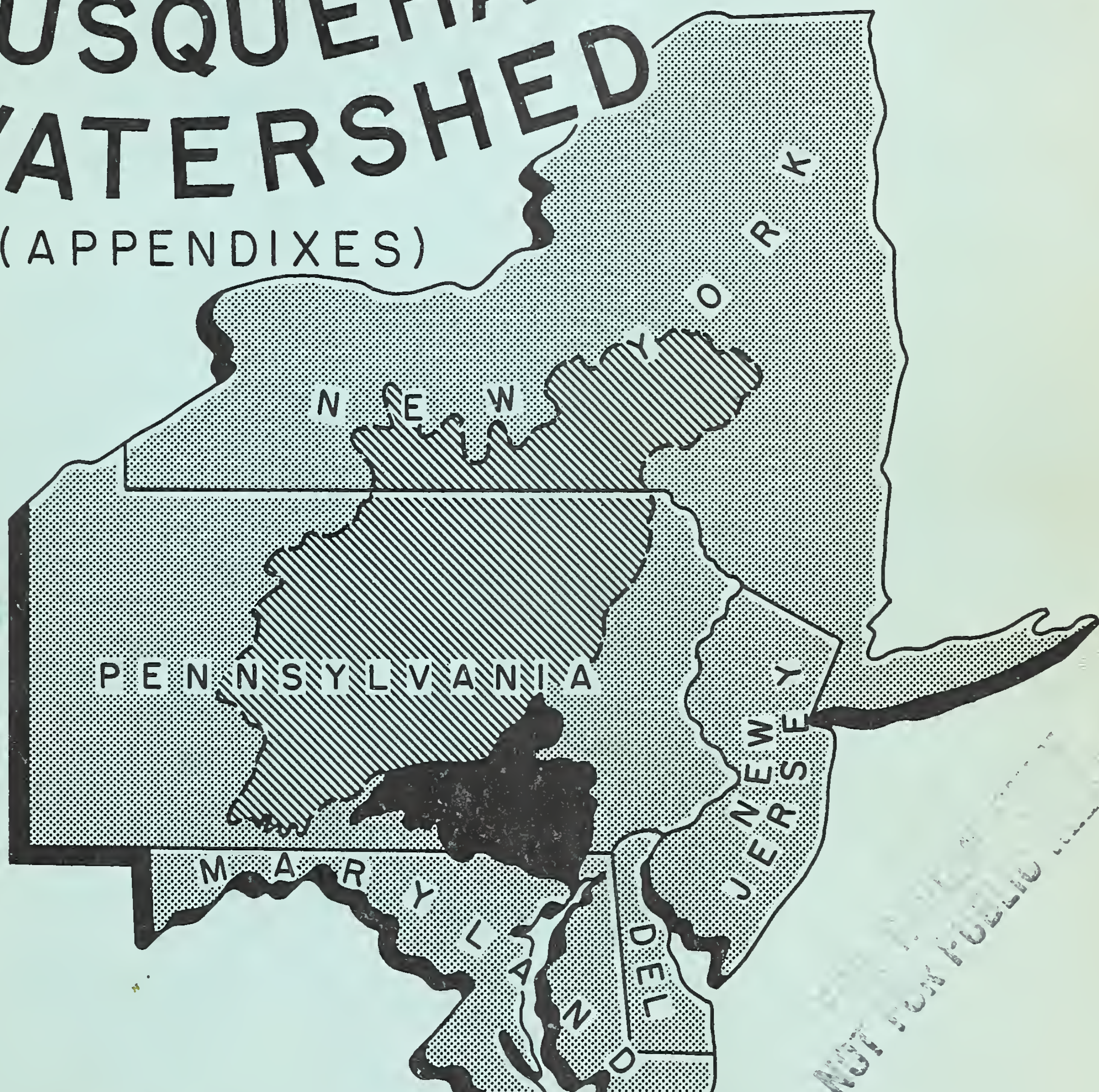
Type of Benefit	Average Annual Benefit	
	(dollars)	
Reduction in Damage Due to Inundation		
Agricultural	4,000	
Non-Agricultural	35,300	
Subtotal		39,300
Reduction in Damage Due to Sediment		
Channel Sedimentation	12,300	
Highway Sedimentation	30,100	
Water Supply Pollution	4,900	
Reservoir Sedimentation	8,200	
Subtotal		55,500
Reduction in Damage Due to Erosion		2,031,900
Land Enhancement		44,000
Other Benefits 1/		
Increased Crop Production	2,442,200	
Increased Pasture Production	596,200	
Increased Woodland Production	692,100	
Savings in Production Costs	543,500	
Subtotal		4,274,000
TOTAL		6,444,700

1/ Benefits which accrue to the owners and operators of the land on which the recommended program is installed.

SURVEY REPORT

LOWER SUSQUEHANNA RIVER WATERSHED

(APPENDIXES)



PROGRAM FOR
RUNOFF AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION

U. S. DEPARTMENT OF AGRICULTURE

0002

MAY, 1952

V, 2-1

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIXES
SURVEY REPORT

LOWER SUSQUEHANNA RIVER WATERSHED

Pennsylvania and Maryland

Program for Runoff and Waterflow Retardation and
Soil-Erosion Prevention

Pursuant to The Act Approved June 22, 1936 (49 Stat. 1570),
as Amended and Supplemented.

TABLE OF CONTENTS

Section

SECTION I - PHYSICAL FACTORS

Table of Contents

List of Tables

List of Figures

LOCATION AND SIZE I

The Lower Susquehanna River Watershed is that area drained by the Susquehanna River from Harrisburg, Pennsylvania, to the Chesapeake Bay. This drainage area is approximately 3,944 square miles of which approximately 93 percent is in the state of Pennsylvania, and the remainder in Maryland. Eleven counties in Pennsylvania and four in Maryland are wholly or partly within the watershed. The area is approximately 100 miles from east to west and 70 miles from north to south at the widest points.

Seven major tributary streams enter the Susquehanna River between Harrisburg and Chesapeake Bay. Those entering from the eastern side of the river are Swatara, Conestoga and Octoraro Creeks; those from the west are Yellow Breeches, Conodoguinet, West Conewago, and Codorus Creeks. The drainage areas of these tributaries range from approximately 210 square miles to 570 square miles. The topography is generally steep and mountainous in the northern portion, gently rolling or nearly level in the central area, and moderately or steeply rolling in the southern portion of the watershed.

CLIMATE

The watershed of the Lower Susquehanna is subject to both continental and marine climatic influences. It experiences a climate intermediate between that of the mountain or upland, typical of the Upper Susquehanna drainage and that climate found directly on the coast.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR

Figure 1

AGR-SCS-UPPER DARBY, PA.
MAY, 1952

Summers in this area have large numbers of warm to hot days, though physically oppressive weather is usually due to the high humidity or moist air masses which enter this region in summer to remain for several days. Lack of air movement during these humid air invasions frequently intensifies the oppressive condition. Winters in this area can be classed as moderate. At Harrisburg, temperatures of zero Fahrenheit occur on the average but one winter in three. Snowfall is moderate, the total annual fall averaging about 30 inches but the ground (except at higher and more protected sites) is snow-covered only about one-third of the time during the winter season. Considerable area of the Lower Susquehanna Watershed has a growing season of 180 to 200 days.

The total annual precipitation (rain and melted snow) in the Lower Susquehanna Watershed averages from 38 to 45 inches. Figure 2 shows the average monthly precipitation at six locations in the watershed.

The Lower Susquehanna River Watershed is in the path of many of the cyclonic disturbances that cross the continental United States from west to east with the interaction of air masses. Precipitation associated with such frontal disturbances may reach flood proportions from more than one type of air mass relationship. Precipitation of moderate intensity, but covering thousands of square miles, is associated with a warm front. When such a front moves slowly, or remains

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR

NORM MONTHLY TEMPERATURE AND PRECIPITATION

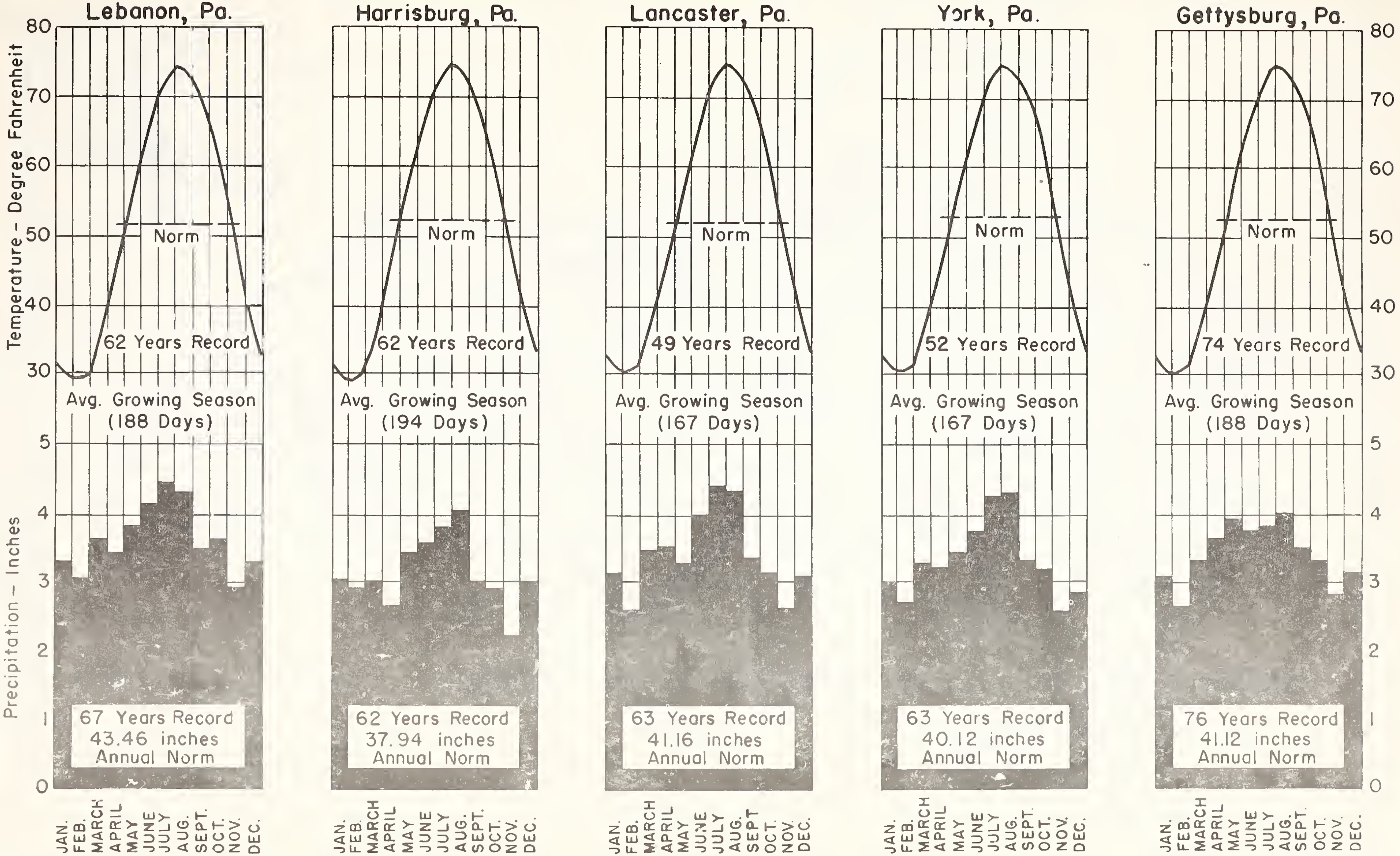


Figure 2

AGR-SCS-UPPER DARBY, PA.

MARCH 1952

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR

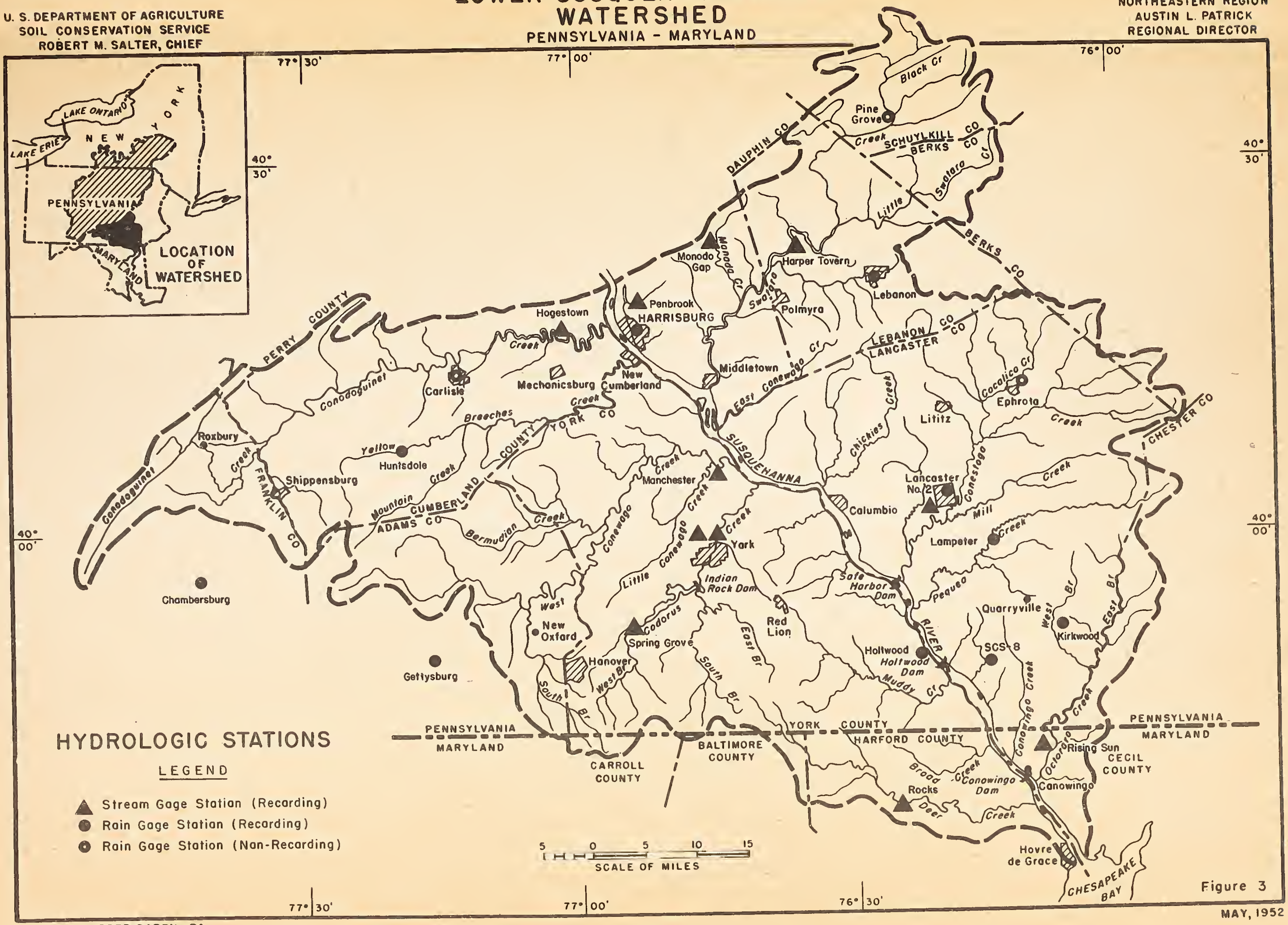


Figure 3

MAY, 1952

AGR-SCS-UPPER DARBY, PA.

virtually stationary over the watershed, the moderate intensity rainfall may continue for a period of days as warm, moist air is forced to rise over a wedge of colder air until it loses its moisture in the form of rain. Basin-wide floods are invariably associated with such stagnant, warm front rains.

The passage of a cold front across the watershed is likely to generate thunderstorm conditions at a number of points along the front. The intensity of a thunderstorm is related to the severity of the reaction between the advancing mass of cold air and the nearly stationary mass of warm air containing large quantities of precipitable moisture. If the reaction is strong, rainfall intensities will reach several inches per hour but the storm duration will be but a few hours at most. The area covered by a single important thunderstorm may be less than 100 square miles but within that area the high intensity precipitation (both rain and hail) may produce high streamflow and flooding on the smaller tributaries far in excess of that from a warm front storm, the greatest damage from which will be found downstream where the flow from several smaller tributaries has combined. While the individual thunderstorm covers but a very small part of the Lower Susquehanna Watershed, the passage of a cold front may generate a series of storms within a short time. Such a series of thunderstorms may produce serious flood conditions over more than one small tributary, giving rise to high upstream damages. Such storms have a high probability of occurrence during the growing season when crop damage is most severe.

A relatively rare type of storm in the Lower Susquehanna Basin is the tropical hurricane. These rotational storms of high wind velocity accompanied by high rainfall intensity, which originate in the southwestern Atlantic, only occasionally strike the coast far enough north to reach the Lower Susquehanna area with flood producing effect. Such storms occuring only during the warmer portion of the year, have occasionally produced severe flooding on tributaries of the Lower Susquehanna River.

The paths of most storms cross the Lower Susquehanna Watershed from the west to east, transverse to the course of the main river. The type of watershed orientation tending to produce the severest type of flood peak, where storm movement and streamflow coincide, is fortunately confined to a few west bank tributaries.

Maps of average annual rainfall show the lowest values in the center of the basin, increasing slightly upstream and to the mouth of the river. The higher portions of the watershed, both east and west of the river, receive, on the average, slightly more rainfall than the low lying section along the river. The differences in average annual rainfall, however, are small and do not account, in a major degree, for variations in streamflow behavior.

Though average monthly precipitation amounts do not vary widely, it should not be assumed that this is an area where drought is unknown and rainfall never excessive. The precipitation total of

a flood producing storm frequently exceeds the monthly normal and in some cases has been two or three times this amount.

Much more variation is found when considering precipitation that falls as snow. Wide variation occurs from year to year, but the northern and highland areas exhibit consistently higher average annual snow falls than lower areas near tide water.

Snow is an important contributor to flood peaks when rapid melting of large amounts accompanies excessive rainfall. Spring snow melt has contributed to flood flows on the Lower Susquehanna Watershed and this condition must be considered a flood hazard.

The depth to which frost penetrates the soil varies considerably from year to year, from area to area within the watershed, and from one vicinity to another within a general area. Local variations are closely associated with soil and moisture conditions and most particularly with type and condition of the vegetative cover.

Ground frost increases the flood hazard, particularly when it is of the concrete frost type, which markedly reduces the infiltration potential. The likelihood of concrete frost formation is reduced as conservation measures and improved vegetative cover are introduced.

GEOLOGY

The Lower Susquehanna River Watershed lies in the Ridge and Valley and Piedmont Provinces. The Ridge and Valley Province includes the southern and eastern slopes of Blue Mountain; and

immediately to the south, the Great Valley section, known as the Shenandoah Valley in Virginia, and called Cumberland Valley in Pennsylvania. The remainder of the watershed is in the Piedmont Province.

Blue Mountain is underlain by sandstone and the area immediately to the south by shales. The ridges of the Ridge and Valley section are made up of resistant sandstone formations elevated by intense folding and faulting. The great valley is underlain by limestone. Granite, gneisses, and schists predominate in the Piedmont.

SOILS AND EROSION

Soils in the watershed are residual. They were considered under three major groups, classified according to underlying bedrock. The locations of the major soil groups are shown in Figure 4.

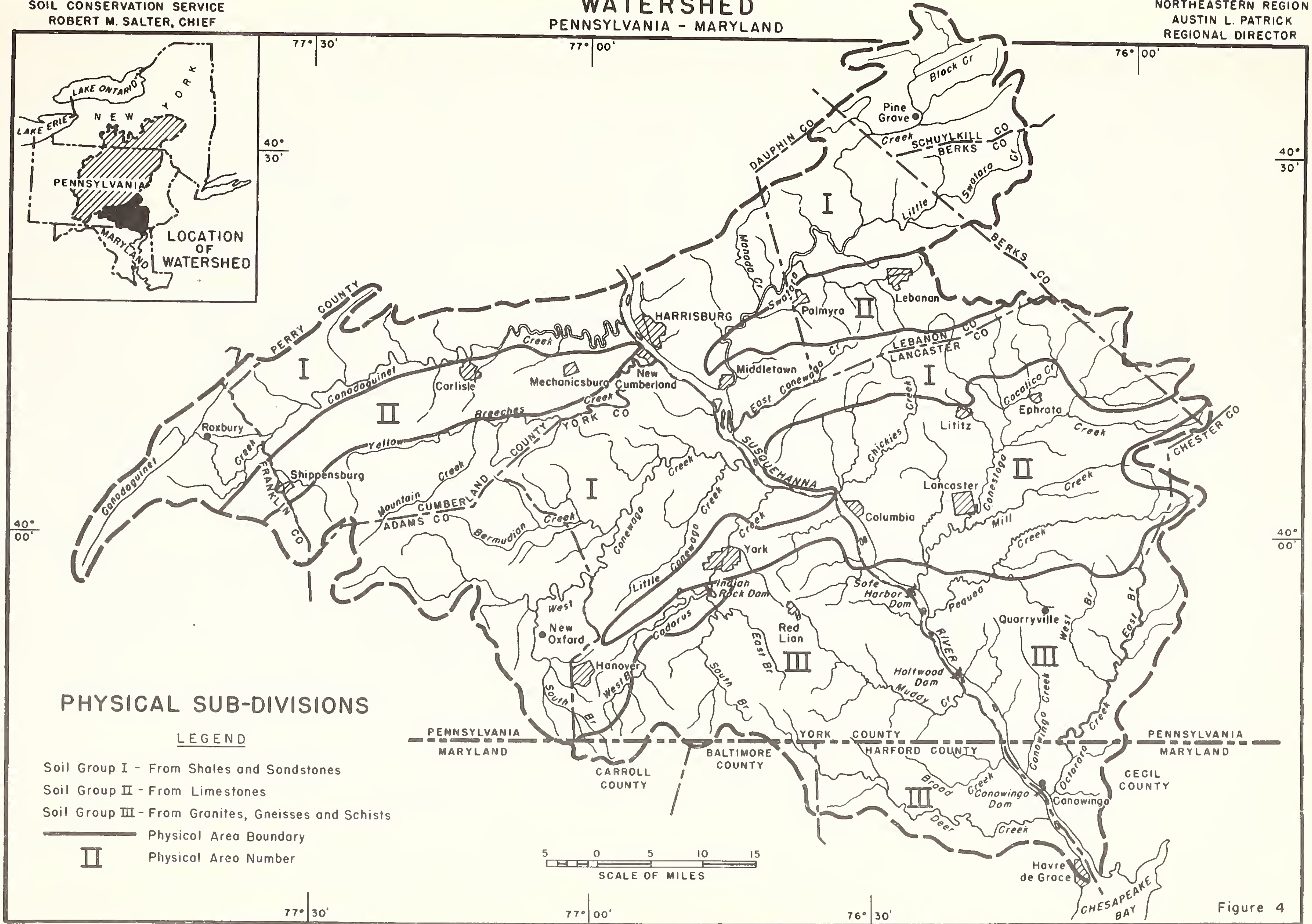
The soils in the northern half of the watershed (group I) are derived from acid shale and sandstone. Much of the upland soil of this group is deep, medium textured, well drained, and has a moderate infiltration rate. The steeper slopes are usually well drained but shallow. Approximately 10 percent of the soils in the area are imperfectly or poorly drained and occur in small scattered areas at the heads of streams and along flood plains.

The largest area of limestone soils (group II) occurs in a valley in the northern half of Lancaster County. A narrow tongue

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR



AGR-SCS-UPPER DARBY, PA.

MAY, 1952

extends westward and includes the city of York. These soils are deep, medium to heavy textured, and well drained. They have moderate to good infiltration rates. Fertility is high and consequently the area is well known for its agricultural production.

Group III includes soils of the Piedmont. When developed on schist and gneiss, they are deep, medium textured, and have good infiltration rates. Some of the ridgetop soils have developed on quartzite. These are light textured and have high infiltration rates. Shallow to moderately deep, slowly permeable soils have developed on the shale and sandstone areas.

PRESENT LAND USE

The uses to which the lands in the watershed are devoted are summarized in Table 1. It will be noted 7 percent of the total area is occupied by towns, roads, streams, etc., and another 5 percent is non-farm openland. Openland totals 66 percent, of which nearly two-thirds is cropland. The land use pattern indicates intensive cultivation of the land devoted to crops. The non-farm openland is represented by areas held for real estate development, golf courses, cemeteries, or municipal holdings.

Cropland accounts for 63, 76, and 57 percent of the land in farms in soil groups I, II, and III, respectively. Similar figures for pasture are 17, 13, and 21 percent.

Table 1. Present Land Use
Lower Susquehanna River Watershed

Land Use	Area in Acres		Percent of Total Area	
Openland	1,662,100		66	
Cropland		1,089,500		43
Pasture		241,700		10
Abandoned, Idle Miscellaneous		202,300		8
Non-Farm Openland		128,600		5
Woodland	685,400		27	
Grazed		19,700		0.7
Ungrazed		665,700		26.3
Roads, Water, Urban etc.	176,700	176,700	7	7
TOTAL	2,524,200	2,524,200	100	100.0

SECTION II - LAND AND WATER ECONOMY

Table of Contents

List of Tables

LAND AND WATER ECONOMY

AREA AND POPULATION

The drainage area represented by the Lower Susquehanna River below Harrisburg, Pennsylvania is 3,944 square miles. Of this area, approximately 3,660 square miles are in the State of Pennsylvania, and the balance in Maryland.

Land in farms totals 1,749,500 acres or 2,734 square miles, equal to 69 percent of the total area. There are 25,200 farms in the watershed, having an average size of 69 acres.

Total population in the watershed (1950) is estimated at 798,000. The largest cities are Harrisburg (89,500), Lancaster (63,800), and York (60,000), all located in Pennsylvania. There are four cities with populations between 10,000 and 50,000, totaling 69,500 persons. An additional 42 urban centers, with a total population of 103,000 range between 1,000 and 5,000 population each.

RESOURCES

Agricultural Land.

The watershed embraces some of the best agricultural land in eastern United States. This highly productive area is confined largely to Cumberland, Lancaster, and York Counties, with smaller areas in Dauphin, Franklin, and Lebanon Counties, and it reflects the occurrence of limestone in the underlying rocks. The availability of limestone also had its influence on productivity of soils lying

adjacent to the limestone area. Limestone soils occupy slightly over a fifth of the total area.

Corn for grain is the most extensively grown crop in the watershed. Other clean tilled crops include tomatoes, potatoes, tobacco, sweet corn, and small fruits. Small grain crops are principally winter wheat, winter barley and spring oats. A significant acreage is also devoted to soybeans. Production of apples and peaches is concentrated in northern Adams and southern Cumberland Counties, although not confined to these counties. A substation of the Pennsylvania State Agricultural Experiment Station is located at Lancaster for work on tobacco.

Production of livestock is a very important farm enterprise. Excellent milk markets in Philadelphia and other nearby cities have encouraged the development of dairy farming. A large quantity of fluid milk is marketed through the Hershey Chocolate Corporation. Fattening of beef cattle, both on pasture and feed lot is extensive. Factors in the development of this industry are the livestock yards in Lancaster and the large quantity of corn grain available. York County, Pennsylvania, ranks at or near the top in the State in poultry and egg production. Very good local and nearby markets for all types of farm produce help to place Lancaster County, Pennsylvania among the first ten counties in the United States in value of total agricultural production. The county contributes

nearly 40 percent of all agricultural production in the watershed, on less than one-third of the cropland.

In the Maryland portion of the watershed, and in Pennsylvania near the Maryland border, a more generalized and extensive agriculture is evident. Large acreages of corn, winter grains, and hay are grown. Dairy and beef cattle and poultry are important farm enterprises. The general topography is more rolling in this area than in the limestone section, hence pastures fit naturally into a good land use program.

Of a total agricultural production in the watershed approaching 150 million dollars in 1945, 26.6 percent, 14.9 percent, 20.9 percent, and 28.3 percent are accounted for by dairy products, other livestock, poultry, and crops respectively.

Forest Land.

The present wood needs of the watershed make importation of both raw materials and finished products necessary. Since only about one-quarter of the watershed is in forest land, it is unlikely that local wood production will ever be sufficient to meet the demand. However, the forest lands are now producing at only about one-half their potential. Under good forest management it should be possible to make up a considerable part of the deficit.

The forests of the Lower Susquehanna Watershed are relatively homogeneous. Oak types on the drier sites and tulip poplar, bass-

wood, white ash and similar species on the bottom lands make up the forests over most of the watershed. Mixed forests (hardwoods and conifers) account for only 13 percent and pure conifer types for only 2 percent.

Repeated heavy cuttings, often in young stands and frequently followed by fire, have resulted in large areas of immature stands. Many of the more desirable species have been largely eliminated and particularly in the coal fields large tracts of land are either denuded or covered with heavy stands of scrub oak. Stands primarily of seedling and sapling sizes, together with stands of larger size trees but with very poor stocking cover more than half of the total forest land area. Many of the trees that are present in the under-stocked older stands are of poor form and undesirable species.

Approximately 19,700 acres, or 9 percent of the farm forest area, are grazed, reducing both watershed protection and timber production values materially.

Table 1. - Present Stand Size Distribution
Lower Susquehanna River Watershed

Stand Size	Acres	Percent
Saw Timber	111,700	16.3
Poorly Stocked Sawtimber	92,500	13.5
Poles	207,700	30.3
Poorly Stocked Poles	65,800	9.6
Seedling and Sapling	154,900	22.6
Poorly Stocked Seedling and Sapling	52,800	7.7
TOTAL	685,400	100.0

Industry.

The watershed is industrially outstanding. Among the larger industries are the Bethlehem Steel Company, with plants at Steelton and Lebanon, and a large quarry operation at Cornwall; Armstrong Cork Company at Lancaster; York Refrigeration Company; Farquhar Farm Equipment Company; and several large paper and wood fiber plants in York and York County; and numerous limestone quarries and lime plants distributed throughout the limestone area. Many of the manufacturing plants are the largest of their types in the world. A great variety of smaller industries is well established throughout the watershed. The high level of industrial activity is reflected in the large number of urban centers and the generally high living standard throughout the watershed. Harrisburg reflects the influence of itsposition as Capitol of Pennsylvania, in the number of State offices, hotel accommodations, State meetings, and related activities. Its largest single industry is railroading, due to the strategic location on many transportation routes.

The area is traversed by the Pennsylvania Railroad main lines between New York, Philadelphia and Harrisburg, and between Baltimore and Harrisburg. The Reading Railroad serves the eastern portion of the watershed, with a main line through Lebanon to Harrisburg, and branch lines to Lancaster, Cumberland, and Schuylkill Counties. West of the Susquehanna River the Western Maryland Railroad provides

service from Harrisburg through York to Gettysburg, and the Reading Railroad as far as Shippensburg. The Maryland and Pennsylvania Railroad connects York and Baltimore.

The Pennsylvania Turnpike traverses the watershed from east to west, crossing the Susquehanna River eight miles south of Harrisburg. The entire watershed is well supplied with a good system of improved roads which are well maintained.

LAND OWNERSHIP

Farmland.

For the most part, farms are owner-operated. The percentage of owner-operated farms in the Pennsylvania portion of the watershed varies from 63 percent in Cumberland County, to 80 percent in Dauphin County. Only 65 percent of the farms are owner-operated in Lancaster County. A small percentage (less than 3 percent) of farms are operated by hired manager. Most farms are individually owned but in a few instances, an individual or a corporation owns several properties mostly operated on a tenant basis.

Forest Land.

Forest land covers approximately 685,400 acres or 27.1 percent of the total watershed area. Of this forested area, 31.5 percent is in farm forests, 55.6 percent is in privately owned

non-farm forests, and 12.9 percent is in public ownership. Table 2 shows present ownership of forest land.

Table 2. Ownership of Forest Land
Lower Susquehanna River Watershed

Ownership	Acres		Percent	
Privately Owned Forest Land:				
Farm	216,000		31.5	
Non-Farm	318,200		55.6	
Subtotal		597,200		87.1
Publicly Owned Forest Land:				
County and Local	9,900		1.5	
State	68,400		10.0	
Federal	9,900		1.4	
Subtotal		88,200		12.9
TOTAL		685,400		100.0

Of the total of 597,200 acres of privately owned forest land approximately 531,900 acres or 89 percent are in Pennsylvania with the remaining 65,300 acres in Maryland.

There are four types of public forest land ownership of appreciable size, all in Pennsylvania: (1) Federal Military Reservation, 9,900 acres; (2) State forests, 44,700 acres; (3) State game lands, 23,700 acres; and (4) county and municipal forests, including parks, 9,900 acres.

SECTION III - HYDROLOGY

Table of Contents

List of Tables

List of Figures

EFFECT OF LAND TREATMENT PRACTICES AND MEASURES ON PEAK FLOW

Land cover conversions, woodland management, and certain of the openland measures included in the needs of the watershed result in an increase in the rate and total amount of infiltration on the area affected. The resultant decrease in surface runoff reduces peak flow and damages due to inundation.

The physical condition of the forest soil is one of the important factors in the effect that the forested area has on flood runoff. Studies of infiltration and soil moisture have shown that an increase in humus and litter depth and an improvement in humus condition (i.e., a change to a more porous type) are reflected in both a higher rate of water intake and a greater water storage capacity.

The effect of woodland measures on flood runoff was determined by comparing average forest conditions in all present stands with those conditions found in the better stands such as would prevail with the recommended program in effect.

On a field inventory of selected subwatersheds, observations were made to determine the average condition and depth of the woodland humus by forest stand size and condition class, and past use or treatment including grazing, burning, logging, and whether or not the area had been cleared for agricultural purposes.

The field observations indicate that burning, grazing and heavy cutting prevent the development of good humus condition. Stands

that have experienced these disturbances have a more compact and shallow humus. The better stocked, older stands showing no evidence of fire, grazing, or of clearing for agriculture, have deeper humus and litter.

The condition and depth of humus in well stocked, ungrazed, unburned stands of an older age class is taken as the condition to be expected with good woodland management. Those stands are by no means ideal; good forest management should result in appreciably better condition.

Infiltration rates of forest soil profiles were correlated with forest floor conditions to permit a hydrologic evaluation of woodland areas. The forest area was grouped into three hydrologic evaluation classes based on infiltration rates for various forest floor conditions. The criteria for defining these classes (like those for the openland) apply to both present conditions and those with the program in effect. The hydrologic evaluation classes are as follows:

Class I (Woodland)

Deep humus of a highly absorptive type. Forest floor undisturbed and uniform.

Class II (Woodland)

Moderately deep humus of an absorptive type. Forest floor relatively undisturbed and uniform.

Class III (Woodland)

Shallow humus disturbed and patchy or deeper humus of a compact, less porous type.

Class IV (Openland)

Hydrologic conditions such as are found in good pasture. Highest openland infiltration. Includes good meadow or hayland.

Class V (Openland)

Infiltration and soil moisture transmission values of an intermediate openland condition. The hydrologic condition found with close growing crops such as small grains. Poor pasture and poor hayland were included in this class.

Class VI (Openland)

Poorest cropland hydrologic conditions. Runoff producing infiltration rates attributable to corn and other row crops.

Other Areas

Includes road, urban and other areas of low permeability.

The areas of the several hydrologic evaluation classes under present conditions and with the recommended program in effect are

given for Conestoga Creek Watershed in table 1. In addition to the acreage, areas are expressed as percentages of the watershed.

The reasons that a portion of the wooded area will remain in Class III under management are: (1) a small area will be grazed; (2) a small area will be burned; (3) logging will destroy the humus on skid trails and log landings, and complete correction is not economically feasible; and (4) small areas of extremely steep topography and shallow, rocky soils will never build up an appreciable forest floor. The reasons for the future area remaining in evaluation Class II are largely natural ones. Because of unfavorable topographic and soil conditions the forest floor cannot be improved to the point where the area will fall in Class I. While forest management will improve these areas appreciably, natural factors prevent them from attaining the optimum condition.

Studies throughout the Northeast have shown that the improvement in humus conditions which results from better forest cover and exclusion of grazing is often followed by a decrease in the amount of concrete soil freezing. The decrease in impervious frost greatly aids infiltration of water into the soil and has a marked affect on the amount of surface runoff from woodland areas.

Since forests are the most common cover in the upper headwater areas and on the steeper slopes, the way in which they are managed plays an important part in management of the watershed for

Table 1. Hydrologic Evaluation Class Area Relationship
Conestoga Creek Watershed Above Lancaster, Pa.

Soil Group	Class	Present		With Recommended Program	
		Acres	% of Total Area	Acres	% of Total Area
I & II Deep Well Drained	VI	52,091	25.28	48,531	23.55
	V	51,122	24.81	32,443	15.74
	IV	28,297	13.73	49,804	24.17
	I	1,459	0.71	17,780	8.63
	II	14,021	6.80	3,334	1.62
	III	6,013	2.92	1,111	0.54
I & II Imperfectly & Poorly Drained	VI	2,428	1.18	2,195	1.07
	V	9,013	4.37	1,944	0.94
	IV	2,199	1.07	9,258	4.49
	I	--	--	9,004	4.37
	II	4,997	2.42	1,690	0.82
	III	6,017	2.92	563	0.27
III Deep Well Drained	VI	1,410	0.68	1,367	0.66
	V	1,424	0.69	998	0.48
	IV	804	0.39	1,266	0.62
	I	788	0.38	8,476	4.11
	II	7,350	3.57	1,589	0.77
	III	2,450	1.19	530	0.26
III Shallow Well Drained	VI	253	0.12	242	0.12
	V	436	0.21	237	0.11
	IV	131	0.07	339	0.16
	I	574	0.28	3,598	1.75
	II	2,248	1.09	674	0.33
	III	1,673	0.81	225	0.11
III Imperfectly & Poorly Drained	VI	33	0.02	23	0.01
	V	323	0.16	34	0.02
	IV	21	0.01	314	0.15
	I	0	--	129	0.06
	II	5	--	24	0.01
	III	150	0.07	8	0.01
	Other	8,350	4.05	8,350	4.05
Total		206,080	100.00	206,080	100.00

adequate supplies of pure water for both domestic and industrial use and in minimizing the damage from excess runoff and sedimentation. In the Lower Susquehanna much of this forest land is in relatively poor condition and the problems of low water flow, sedimentation and flood damages have been aggravated. Although the percent of watershed land in forest cover is not very high, forest land because of its location and poor hydrologic condition, is an important contributor to excess runoff.

Openland hydrologic evaluation classes follow closely the type of openland use to which each area is put. Most desirable use from a hydrologic standpoint is the raising of crops of perennials and of those annuals which need not be replanted each year. Least desirable are the row crops which must be cultivated during the growing season. Intermediate between these are the close-growing crops such as the small grains. The program calls for changes in the areas devoted to the various openland uses as a measure toward an improved watershed hydrologic condition.

Changes in land use will result in the retirement of some openland to woodland, and conversion, within openland, to the classes having higher infiltration rates. Increased areas in evaluation Class IV will be derived almost entirely from areas now in Classes V and VI. The total net change will provide an improvement in hydrologic conditions as well as reduce soil erosion.

REDUCTION IN PEAK DISCHARGE

The following procedures were used to determine: the infiltration rates of various evaluation classes; the amount of reduction in peak discharge caused by land use changes; the additional effect of woodland and openland measures; and the resulting total reduction in peak discharge.

Infiltration.

Infiltration data, derived largely from infiltrometer studies, were used to establish infiltration rates for the major soil and cover types found in the watershed. Each of the many soil types was assigned to one of three soil behavior groups according to its infiltration characteristics (Table 2). Infiltration rates applicable to the six evaluation classes were assigned to each of the three soil groups. An example for the Conestoga Creek Watershed is shown in table 3.

The changes in infiltration rate during a storm were found to be most satisfactorily accounted for by the use of a ϕ curve for each evaluation class (figure 5). A ϕ curve differs from a curve of infiltration rate in that any point on the ϕ curve represents an average value for the infiltration that has taken place in the elapsed time from the start of precipitation. These curves of necessity represent average conditions for the evaluation class but their use permits a satisfactory analysis of the runoff producing conditions of the watershed. The ϕ curves were used in the analysis of runoff

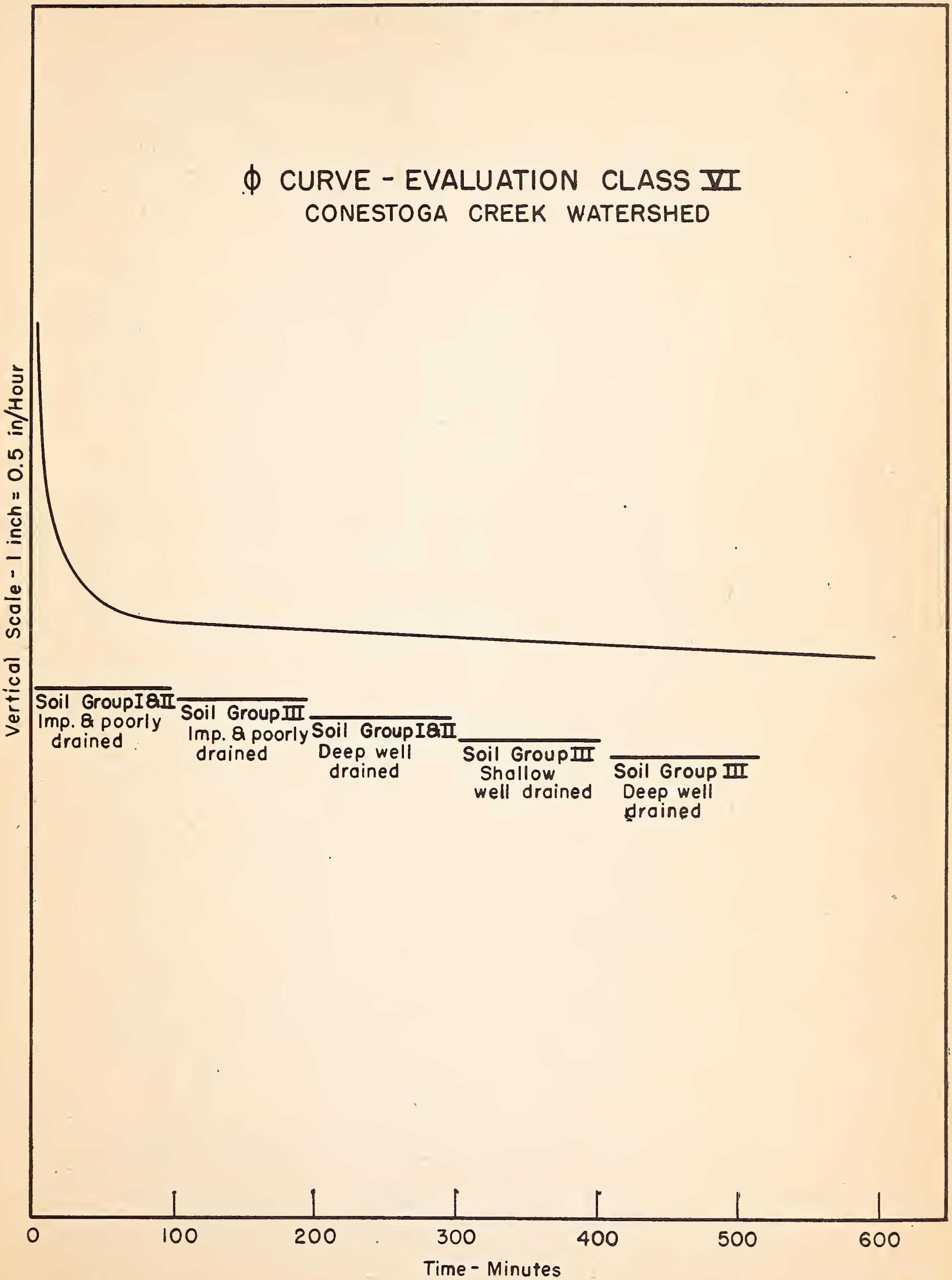

ϕ CURVE - EVALUATION CLASS VI
CONESTOGA CREEK WATERSHED
Vertical Scale - 1 inch = 0.5 in/Hour
Soil Group I & II Imp. & poorly drained
Soil Group III Imp. & poorly drained
Soil Group I & II Deep well drained
Soil Group III Shallow well drained
Soil Group III Deep well drained
0
100
200
300
400
500
600
Time - Minutes

Table 2. Major Soil Group Areas for Hydrologic Evaluation
Lower Susquehanna River Watershed

Soil Group	Soil Depth & Drainage	Representative Soil	Representative Soil Description	Other Soils
I Shale & Sandstone	Deep, well drained.	Bucks silt loam.	Indian red or reddish-brown, friable, silt loam over red to purplish-brown silty clay loam or silty clay and grading into soft, purplish sandstone. Good agricultural soil.	Lansdale Brecknock
	Shallow, imperfectly & poorly drained.	Croton loam.	Dark grayish-brown over dull gray structureless loam over pale yellowish-gray heavier loam. At 18-30" a hardpan horizon occurs. Used mainly for hay, small grain & pasture.	Readington
II Limestone	Deep, well drained.	Hagerstown.	Grayish-brown to dark brown silt loam, mellow and friable over brown, heavy silt loam grading into yellowish-brown to reddish-brown clay. Inherently productive. Well adapted to general farm crops.	Duffield
	Shallow, imperfectly & poorly drained.	Guthrie.	Dark colored surface soils over gray-brown subsoils. Used mainly for pastures.	Lawrence
III Schist Gneiss	Deep, well drained.	Chester silt loam.	Brown, friable, silt loam containing some gritty material, resting on a brownish-yellow gritty loam and grading into silty clay loam. Highly productive soils.	Glenelg Neshaminy
	Shallow, well drained.	Manor stony loam.	Yellowish-brown heavy loam resting on yellow clay loam. Both soil & subsoil contain many flat angular rock fragments.	Edgemont
	Imperfect & poorly drained	Glenville silt loam.	Yellowish, friable silt loam mottled at moderate depth & occupying colluvial positions. Used for pasture, hay and general crops.	Worsham

Table 3. Infiltration Rates
Values of f_c in Inches Per Hour at 600 Minutes

Conestoga Creek Watershed, Pennsylvania

Lower Susquehanna River Watershed

Soil Groups I & II

Evaluation Class	Deep, Well Drained	Imperfectly and Poorly Drained
Class I	0.79	0.42
Class II	0.56	0.30
Class III	0.51	0.27
Class IV	0.56	0.30
Class V	0.51	0.27
Class VI	0.45	0.24

Soil Group III

Evaluation Class	Deep, Well Drained	Shallow, Well Drained	Imperfectly and Poorly Drained
Class I	1.26	1.05	0.52
Class II	0.90	0.75	0.38
Class III	0.81	0.67	0.34
Class IV	0.90	0.75	0.38
Class V	0.81	0.67	0.34
Class VI	0.72	0.60	0.30

from a series of storms developed for each area considered.

Land Use Changes.

The procedure used in determining the amount of peak flow reduction to be expected from land use changes and program measures follows a logical series of steps consisting of statistical and graphical analyses applied to the principal factors affecting flood damages. These steps are described below.

Sample tributaries for determining the hydrologic effect of the program were selected to represent the three major soil areas of the watershed. The samples are the watersheds above the gaging stations listed as follows:

Codorus Creek Watershed at Spring Grove, Pennsylvania

Conestoga Creek Watershed at Lancaster, Pennsylvania

Swatara Creek Watershed at Harper Tavern, Pennsylvania

A series of flood producing storms covering the range from minimum to maximum damage were composited for each of the sample subwatersheds. Published and unpublished records of precipitation amounts and intensities, furnished largely by the U. S. Weather Bureau, were used in determining the storm values. The procedure followed is described below and illustrated in figures 6 and 7.

Relationship of Discharge (Q) to Runoff (Y).

For each of the sample watersheds, United States Geological Survey records of streamflow were utilized to determine the peak

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER
WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR

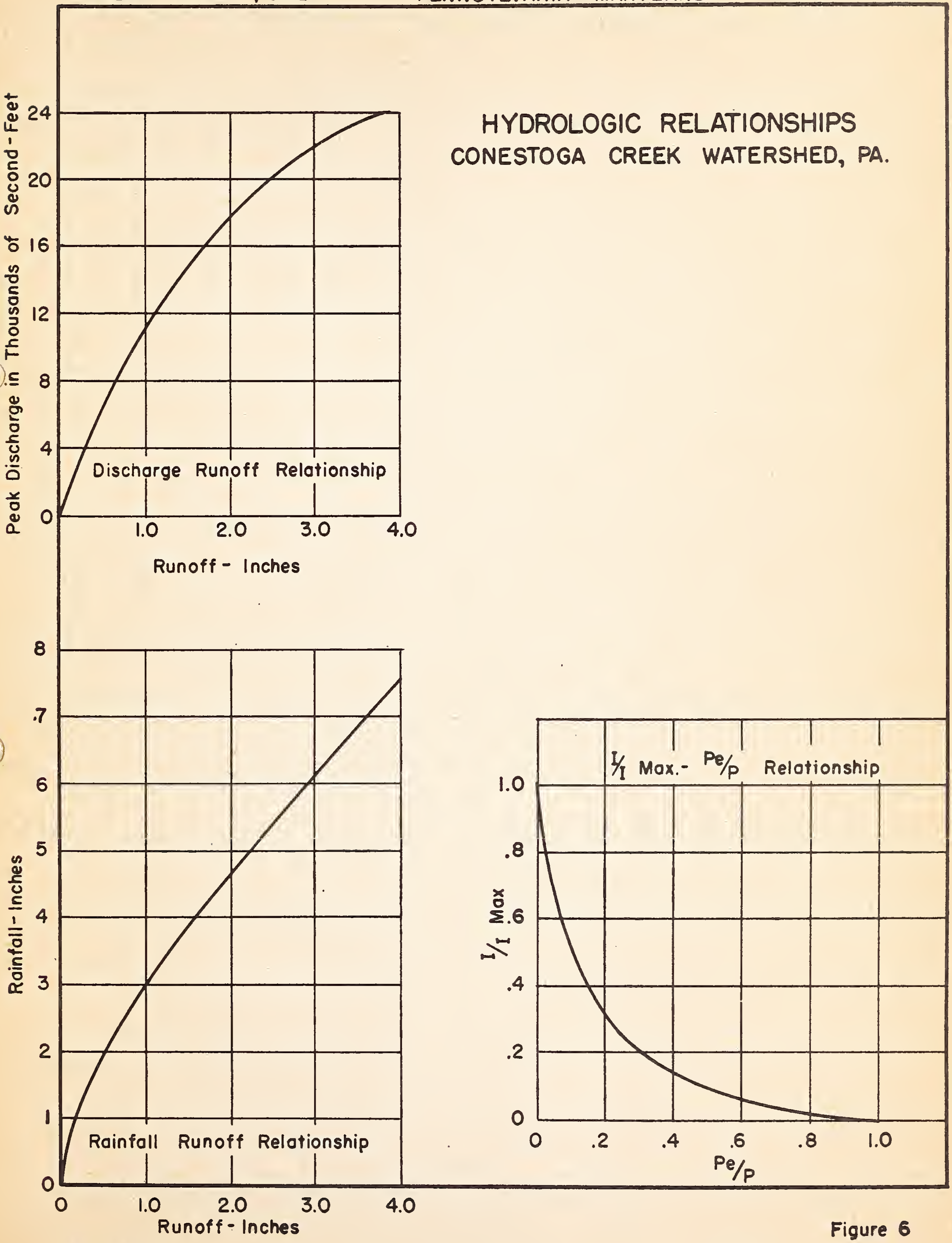
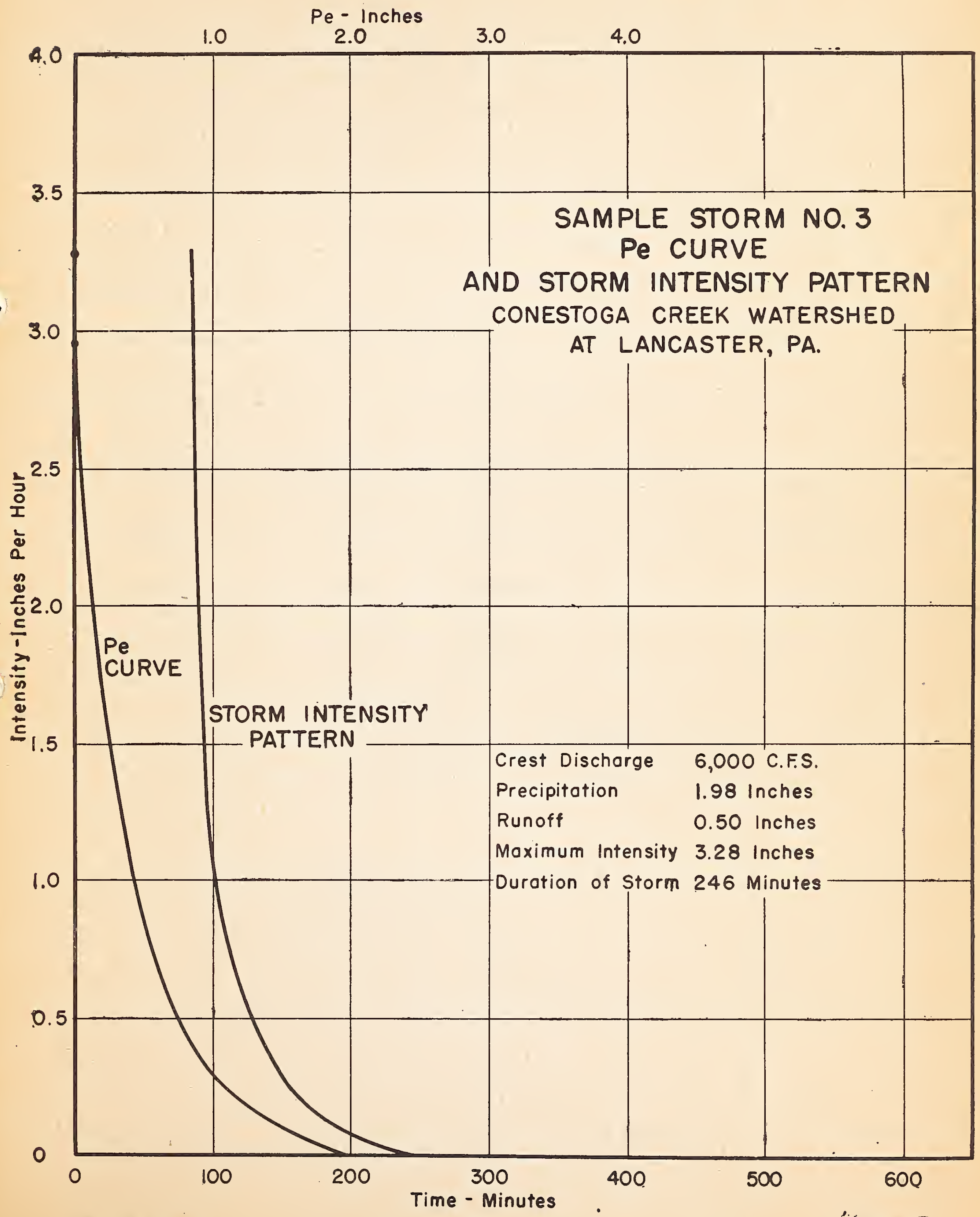


Figure 6


Pe - Inches
1.0
2.0
3.0
4.0
SAMPLE STORM NO. 3
Pe CURVE
AND STORM INTENSITY PATTERN
CONESTOGA CREEK WATERSHED
AT LANCASTER, PA.
Intensity-Inches Per Hour
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Pe CURVE
STORM INTENSITY PATTERN
Crest Discharge 6,000 C.F.S.
Precipitation 1.98 Inches
Runoff 0.50 Inches
Maximum Intensity 3.28 Inches
Duration of Storm 246 Minutes
0
100
200
300
400
500
600
Time - Minutes

discharge and surface runoff for all important floods of record. For the latter determination, individual flood hydrographs were constructed on which were plotted curves of base flow assignable to ground water accretions. The area between the two curves was determined and its value in watershed area depth was plotted against the peak discharge. The curve showing the average relationship between peak discharge (designated Q) in second-feet runoff (designated Y) in equivalent depth in inches over the watershed was drawn from the series of points so plotted.

Relationship of Precipitation (P) to Runoff (Y).

U. S. Weather Bureau records of daily and hourly amounts of precipitation were used to determine the rainfall contributing to the peak discharge. Rainfall at the stations in and immediately adjacent to the watershed was weighted by the Horton-Theissen method to determine the average inches depth on the watershed contributing to the flood crest. Precipitation so determined (designated P) was plotted against the corresponding runoff (Y) in the same unit of measure.

Relationship of Pe/P to I/I max.

This relationship was determined from 5-minute intensity data of 44 storms at Binghamton, New York, in the following manner;

the actual 5-minute intensities for each storm were arranged in descending order of magnitude. For each storm the individual 5-minute intensities (I) were each divided by the maximum 5-minute intensity (I max), and the corresponding Pe values (quantity of rainfall that fell at an equal or greater intensity) were each divided by the total storm rainfall (P), thus providing two sets of ratio values that were plotted I/I max against Pe/P. A curve indicating the average relationship was drawn resulting in a dimensionless diagram. The slope of this curve determined from its tangent at several representative points and expressed in units of abscissa over ordinate is designated N. This value is used in determining intensity--duration relationships during the storm.

The above relationships provided the basis for development of a series of storms correlating discharge, precipitation, runoff and maximum intensity. Maximum intensity for each of the storms was determined by analysis of many historical storms. For each of the storms a Pe curve and a storm intensity diagram were computed as shown in table 4 and plotted, figure 7. The Pe curve shows at each point the quantity of rain falling at a rate equal to or greater than the corresponding intensity, a quantity sometimes called "excess precipitation". The time on the storm pattern for any intensity shows the length of time for which an equal or greater intensity

prevailed during the storm. The time values are designated by the symbol Te (duration of time of excess).

Storm No. 3 for Conestoga Creek produces a peak discharge of 6,000 second-feet as shown in table 5. Based on this peak discharge, the corresponding values of Y, P, and I max were determined from the above-described relationships. From the discharge-runoff relationship a peak discharge of 6,000 second-feet accompanies 0.50 inches of runoff; from the P-Y curve, 0.50 inches of runoff is derived from 1.98 inches of rainfall; an analysis of selected storms shows that 1.98 inches of rainfall has a maximum intensity of 3.28 inches per hour. From the I/I max-Pe/P curve, the values of Pe/P were taken to correspond with each of the selected values of I/I max (table 4). Both table 4 and figure 7 show that the total rainfall of 1.98 inches fell during a period of 246 minutes.

The Pe and Te diagrams, in conjunction with the ϕ curves for the several evaluation classes make possible the evaluation of the recommended land conversion phase of the program. To obtain the Pe value for each class and soil group, the ϕ curve was superimposed upon the storm pattern so that the base lines coincided and the zero time line of the ϕ curve was positioned on such a time line that computed runoff agreed with measured. The Pe values for a given evaluation class were found on the Pe scale horizontally opposite to the point of intersection of the ϕ curve and Te curve. Multiplying this Pe value by the percent of the tributary area in that

evaluation class (table 4) gave a runoff value for that class. The summation of these values for all the classes in the sample watershed gives the total computed runoff. Table 5 illustrates this calculation for storm No. 3 on Conestoga Creek. The computed runoff agreed very closely with the measured runoff.

The Pe values were then multiplied by the corresponding recommended percent of area in each evaluation class, and the products added to determine the runoff under future conditions. By comparing the computed runoff under present conditions with the future computed runoff, the percent reduction in peak flow that would result from the needed land use changes was found.

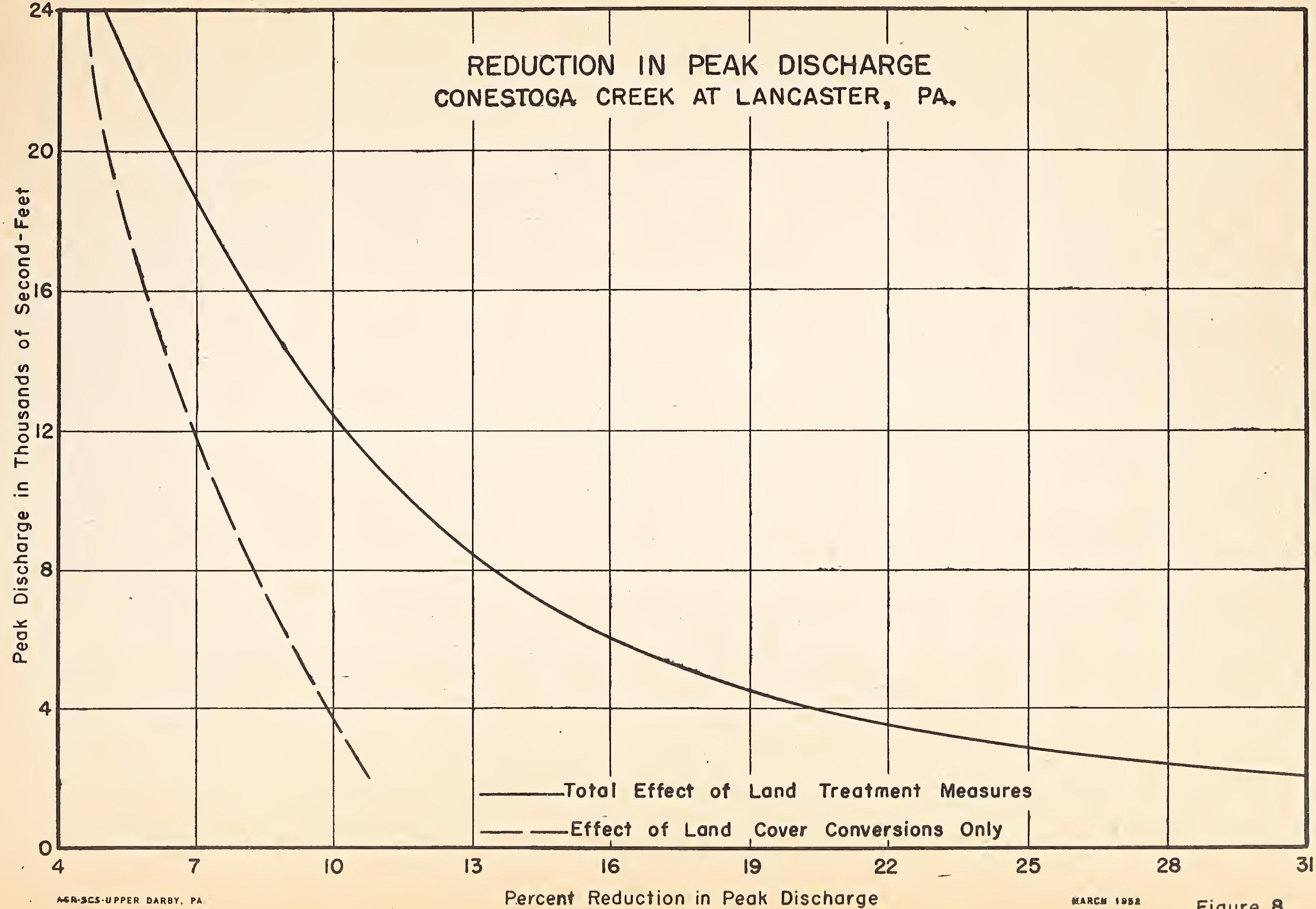
Additional detention storage due to certain measures was conservatively accounted for on the basis of .05 inch per inch of estimated additional humus accumulation in woodlands and .05 inch depth for openland acreage to be placed under contour tillage. From the above calculations for storm No. 3 on Conestoga Creek, the total program would result in a 16.2 percent reduction in peak discharge (figure 8 and table 5).

From the sample tributary analysis, a generalized series of percent reduction - drainage area - frequency curves was drawn for each of the three soil group areas. These curves provided the basis for determining, for each subwatershed, the percent reductions in peak discharge and associated reduction in damage due to inundation by flood flows (figures 9, 10, and 11).

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR



AGR-SCS-UPPER DARBY, PA.

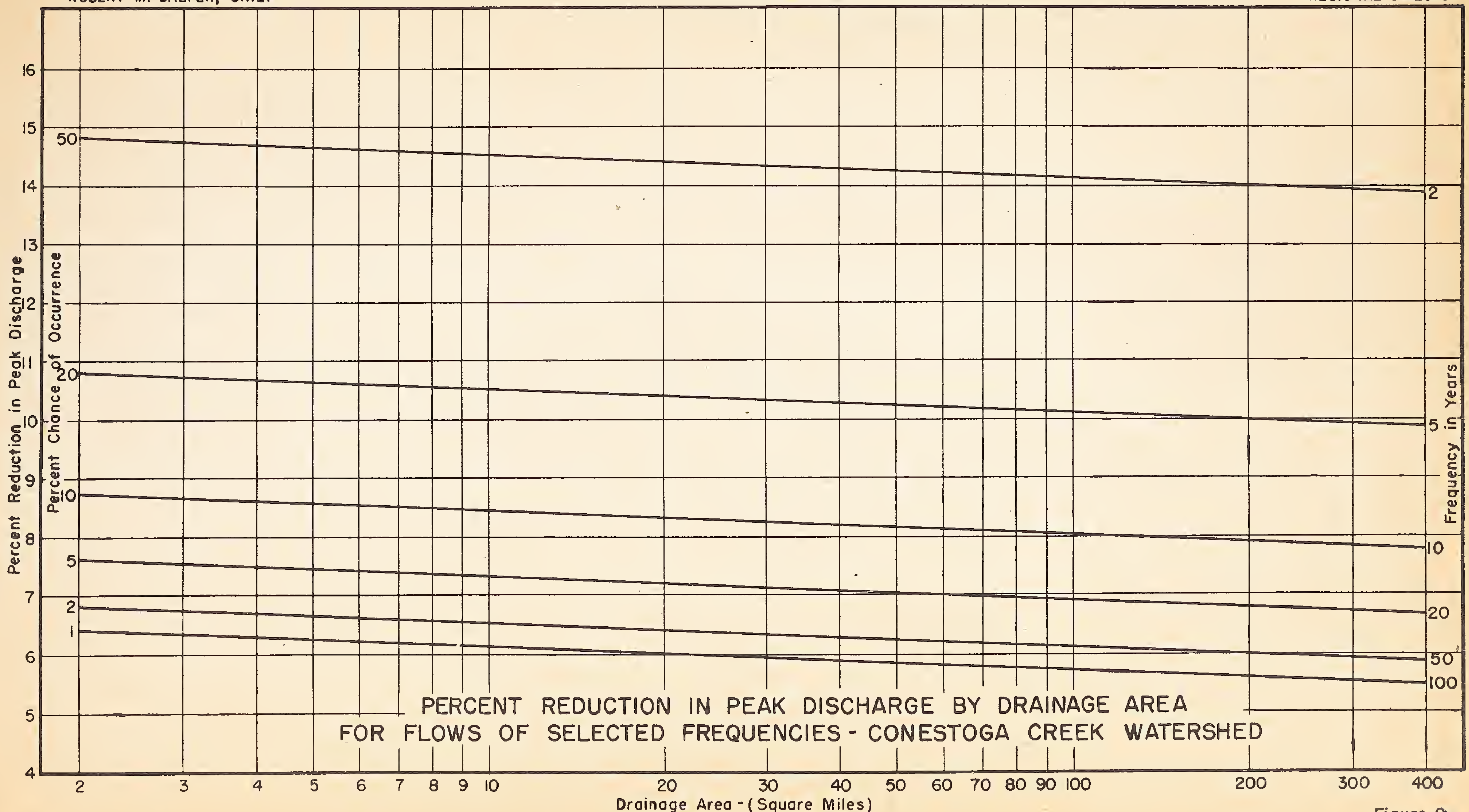
MARCH 1952

Figure 8

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR



PERCENT REDUCTION IN PEAK DISCHARGE BY DRAINAGE AREA
FOR FLOWS OF SELECTED FREQUENCIES - CONESTOGA CREEK WATERSHED

AGR-SCS-UPPER DARBY, PA

MARCH 195[illegible]

Figure 9

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR

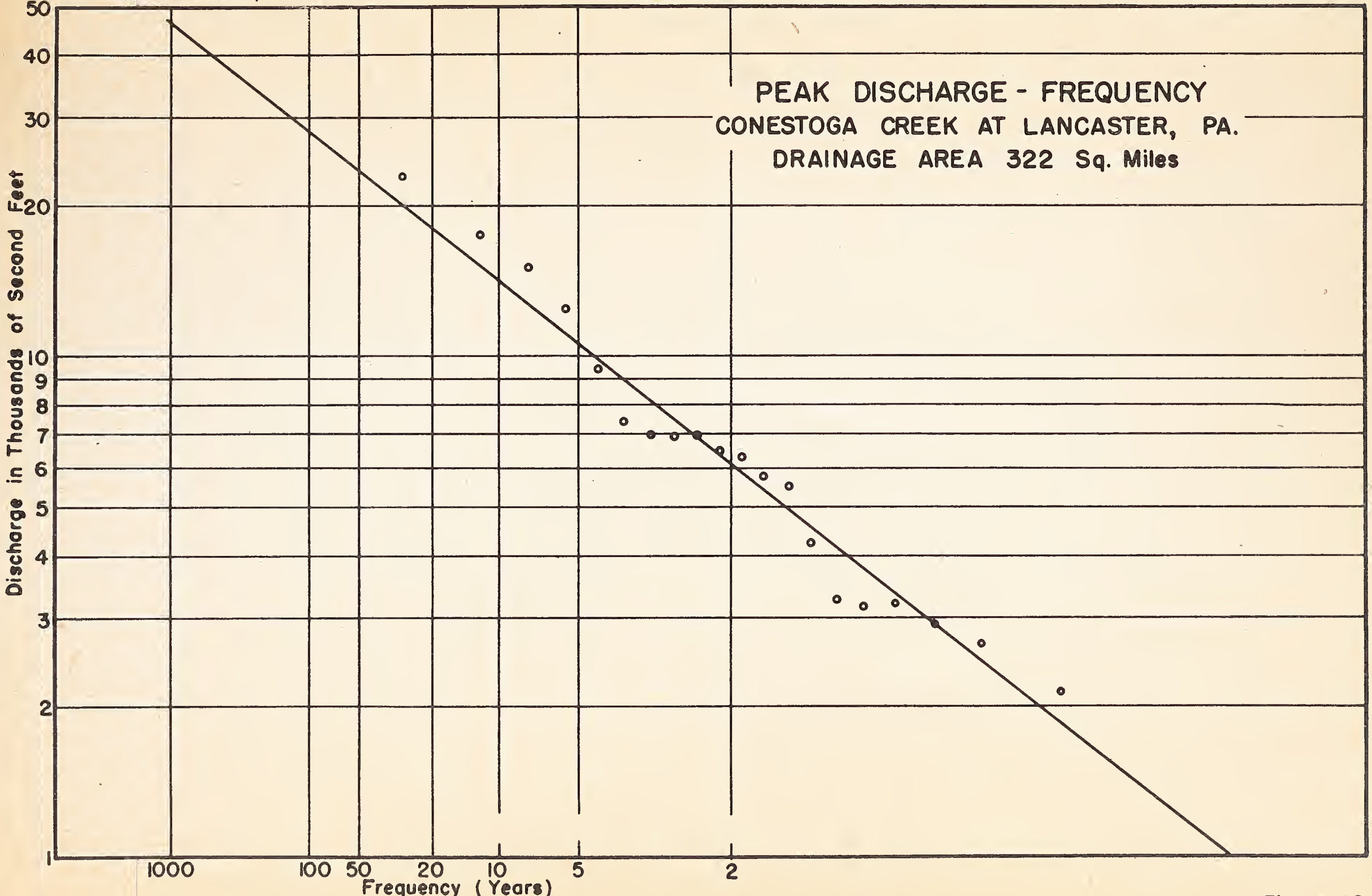


Figure 10

AGR-SCS-UPPER DARBY, PA.
MARCH 1952

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR

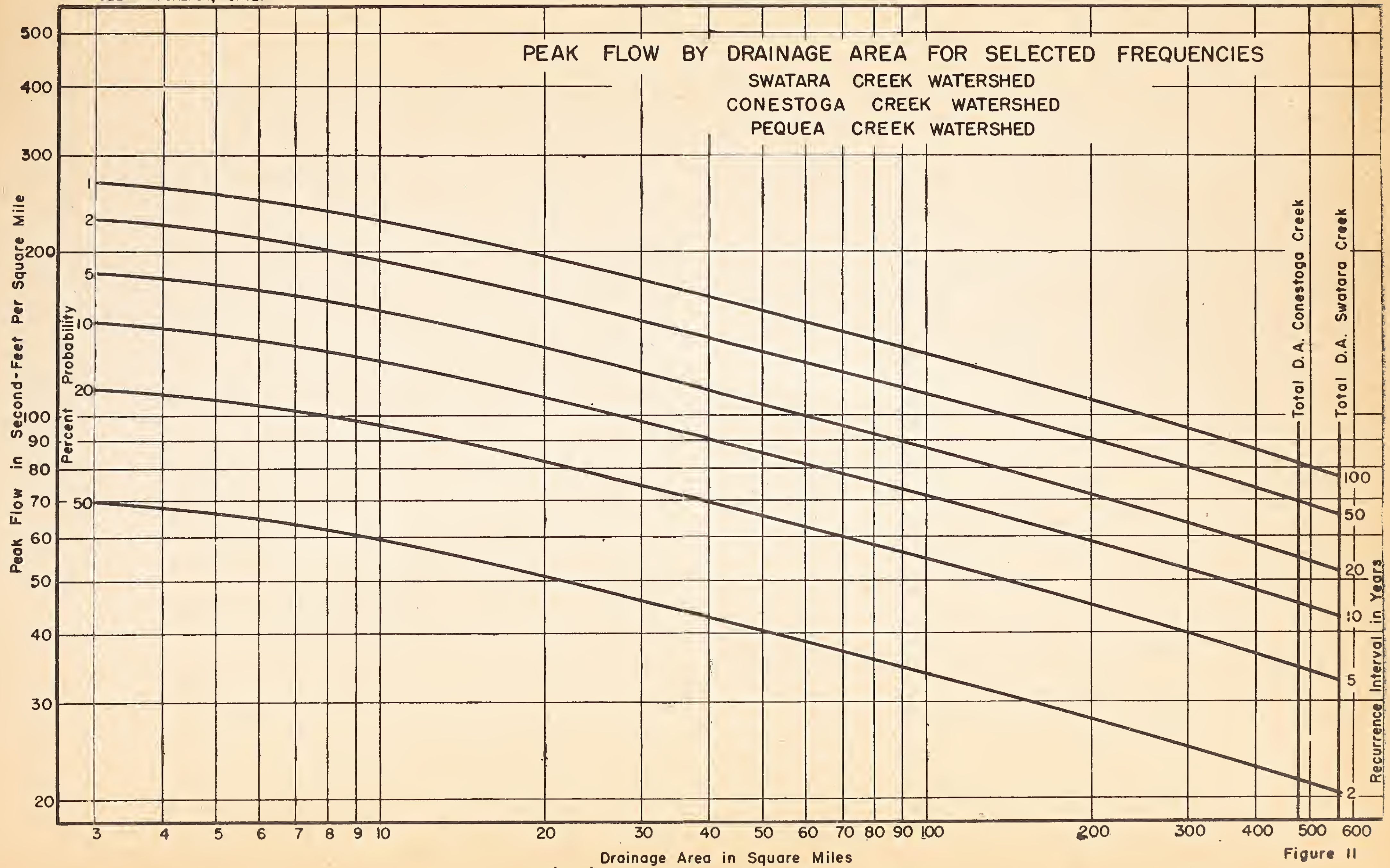


Figure II

AGR-SCS-UPPER DARBY, PA.

MARCH 1952

Table 4. Pe - Storm Pattern Work Sheet
Conestoga Creek Watershed
At Lancaster, Pa.

Storm # 3

Q = 6000 c.f.s. P = 1.98 inches Imax = 3.28 in./hr. Y = .50 inches

T = 4.1049 hours = 246 minutes $\frac{T}{3}$ = 1.3683 hours $\frac{P}{Imax}$ = .603659

$\frac{I}{Imax}$	$\frac{Pe}{P}$	N	I	Pe	Te	$\frac{2Te}{3}$	$\frac{T}{3} + \frac{2Te}{3}$ hrs.	$\frac{T}{3} + \frac{2Te}{3}$ min.
1.0	0	.055	3.28	0	0.0332	0.0221	1.3904	83
0.9	.006	.111	2.95	0.01	0.0670	.0447	1.4130	85
0.8	.021	.168	2.62	0.04	0.1014	.0676	1.4359	86
0.7	.042	.231	2.30	0.08	0.1394	.0929	1.4612	88
0.6	.067	.305	1.97	0.13	0.1841	.1227	1.4910	89
0.5	.104	.408	1.64	0.21	0.2463	.1642	1.5325	92
0.4	.152	.571	1.31	0.30	0.3447	.2298	1.5981	96
0.3	.220	.800	.98	0.44	0.4829	.3219	1.6902	101
0.2	.315	1.411	.66	0.62	0.8518	.5679	1.9362	116
0.1	.480	2.641	.33	0.95	1.5943	1.0629	2.4312	146
0.05	.665	3.867	.16	1.32	2.3343	1.5563	2.9246	175
0.00	1.000	6.800	0	1.98	4.1049	2.7367	4.1050	246

III

Table 5. Runoff Reduction Determination -
Evaluation Class Conversion

Conestoga Creek Watershed at Lancaster, Pa. D.A. 322 Sq.Mi.

Storm
Number 3 P = 1.98 in. Y = 0.50 in.
Coincidence at 60 min. Qp = 6000 sec.ft.

Soil Group	Evaluation Class	Present Conditions			Recommended Program	
		Area %	Pe	% In.	Area %	% In.
I & II Deep Well Drained	VI	25.28	.63	15.9264	23.55	14.8365
	V	24.81	.49	12.1569	15.74	7.7126
	IV	13.73	.37	5.0801	24.17	8.9429
	I	0.71	.11	0.0781	8.63	0.9493
	II	6.80	.21	1.4280	1.62	0.3402
	III	2.92	.30	0.8760	0.54	0.1620
I & II Imperfectly & Poorly Drained	VI	1.18	.86	1.0148	1.07	0.9202
	V	4.37	.71	3.1027	0.94	0.6674
	IV	1.07	.53	0.5671	4.49	2.3797
	I	---	.21	--	4.37	0.9177
	II	2.42	.32	0.7744	0.82	0.2624
	III	2.92	.40	1.1680	0.27	0.1080
III Deep Well Drained	VI	0.68	.44	0.2992	0.66	0.2904
	V	0.69	.33	0.2277	0.48	0.1584
	IV	0.39	.22	0.0858	0.62	0.1364
	I	0.38	.05	0.1900	4.11	0.2055
	II	3.57	.12	0.4284	0.77	0.0924
	III	1.19	.20	0.2380	0.26	0.0520
III Shallow Well Drained	VI	0.12	.51	0.0612	0.12	0.0612
	V	0.21	.40	0.0840	0.11	0.0440
	IV	0.07	.29	0.0203	0.16	0.0464
	I	0.28	.08	0.0224	1.75	0.1400
	II	1.09	.16	0.1744	0.33	0.0528
	III	0.81	.22	0.1782	0.11	0.0242
III Imperfectly & Poorly Drained	VI	0.02	.79	0.0158	0.01	0.0079
	V	0.16	.63	0.1008	0.02	0.0126
	IV	0.01	.47	0.0047	0.15	0.0705
	I	---	.19	---	0.06	0.0114
	II	---	.29	---	0.01	0.0029
	III	0.07	.37	0.0259	0.01	0.0037
Other		4.05	(.75) (1.98) 1.49	6.0345	4.05	6.0345
TOTAL				50.1928		45.6461

Table 5. (Cont.) Runoff Reduction Determination

Effect of changes in evaluation classes:

$$\frac{50.1928 - 45.6461}{50.1928} = 9.06\% \text{ reduction}$$

Effect of increased humus on detention storage:

Evaluation Class	Average Inches Humus Depth	Percent Area Present	Percent Area Future	% Area Change	Depth % Area Change
I	2.87	1.37	18.92	+17.55	+50.37
II	1.58	13.88	3.55	-10.33	-16.32
III	0.73	7.91	1.18	- 6.73	- 4.91
					+29.14

Total Depth-% Area Increase - 29.14 x .05" (Detention storage of increased humus) = 1.457% inches.

Effect of contour measures on detention storage:

42.3% area x .05" = 2.115% inches.

Summary:	Storage (% inches)	Runoff (% inches)
Present condition of runoff		50.19
Effect of changes in evaluation classes	4.55	45.64
Effect of increased woodland humus on detention storage	1.46	44.18
Effect of contour measures on detention storage	2.12	42.06

Total effect of recommended land treatment program:

$$\frac{50.19 - 42.06}{50.19} = 16.20\%$$

FLOOD FREQUENCY

It is the thesis of statisticians that virtually every continuous distribution of observed values, each value being subjected to identical multitude of varying causes, is related to the normal distribution.

For a distribution of observed values to meet the requirements of a normal distribution it must be continuous. Values near the mean must occur more frequently than extreme values, and it must range from minus infinity to plus infinity.

Distribution of observed peak discharges (in cubic feet per second) are not normally distributed, however, the logarithms of these flows are normally distributed.

Any normal distribution is completely described by its mean and standard deviation. For every magnitude in terms of standard deviations above or below the mean, there is a fixed ratio of events exceeding that magnitude to the total number of events. For example, 15.9 percent of all events exceed a value one standard deviation greater than the mean, while 84.1 percent of all events exceed a value one standard deviation less than the mean. An illustrative example of discharge-frequency plotting is shown graphically on figure 10.

An illustrative example of a detailed frequency computation follows this discussion of procedures. A continuous distribution of

annual maximum, instaneous peak flows were recorded for period of record. Inasmuch as the logarithms of the flows are normally distributed, the mean and standard deviation were computed for the logarithms. Capital "X" in the example represents the logarithm of a single flow, and the lower case "x" represents the deviation of a single logarithm from the mean "M" of the logarithms. The sum of the logarithms and the sum of the square of the logarithms are obtained in a single cumulative operation on an automatic calculator. The square of the sum divided by the number of events is subtracted from the sum of the squares in order to obtain the sum of the squared deviations from the mean. This is a short cut operation, which eliminates a large amount of tedious calculation. The sum of the squared deviations is divided by the number of events, less one (1), in order to obtain the variance. The square root of the variance is the standard deviation ($\bar{S}$).

Skewness is a term for the degree of distortion from symmetry exhibited by a frequency distribution. Since the distance between the mean and mode in moderately skewed distributions is three times the distance between the mean and the median, it may be written as follows:

$$\text{Approx. Skew} = \frac{(3)\ (\text{Mean} - \text{Median})}{\text{Standard Deviation}}$$

Where the curve is skewed up the extremely large values will increase the value of the mean. The coefficient will then be a positive value. If the distribution is skewed down, the extreme

cases will reduce the value of the mean. This makes it smaller than the mode and results in a negative coefficient of skewness. Since the coefficient of skewness was relatively small, no correction of the curve was made.

Sample Peak Discharge-Frequency Calculation

Conestoga Creek at Lancaster, Pa. D.A. 322 Sq. Mi.

Period of Record 1929 to date

Type of Gage:-Staff Recording Water-Stage

Source of Data Water Supply Papers U.S.G.S.

Water Year	Peak Q (cfs)	(Log_{10}) of Peak Q	$(Log_{10})^2$	Order No.	Plotting Position
1951	8,350				
50					
49					
48	3,260	3.513	12.341169	15	72.1
47	2,130	3.328	11.075584	20	96.6
46	12,400	4.093	16.752649	4	18.1
45	7,370	3.867	14.953689	6	27.9
44	6,900	3.839	14.737921	8	37.7
43	5,700	3.756	14.107536	12	57.4
42	17,300	4.238	17.960644	2	8.3
41	3,200	3.505	12.285025	17	81.9
40	6,960	3.843	14.768649	7	32.8
39	6,450	3.810	14.516100	10	47.5
38	6,280	3.798	14.424804	11	52.5
37	3,240	3.511	12.327121	16	77.0
36	6,890	3.838	14.730244	9	42.6
35	2,900	3.462	11.985444	18	86.8
34	15,000	4.176	17.438976	3	13.2
33	22,800	4.358	18.992164	1	3.4
32	5,480	3.739	13.980121	13	62.3
31	4,220	3.625	13.140625	14	67.2
30	2,680	3.428	11.751184	19	91.7
29	9,400	3.973	15.784729	5	23.0
		75.700	288.054378		

$$n = 20$$

$$m = \Sigma X/n = 3.785$$

$$\Sigma(X)^2 = 288.054378$$

$$(\Sigma X)^2/n = 286.524500$$

$$\Sigma(x)^2 = \Sigma(X)^2 - (\Sigma X)^2/n = 1.529878$$

$$\Sigma(X)^2 / n - 1 = 0.080520$$

$$\bar{s} = \sqrt{\Sigma(x)^2 / n-1} = 0.284$$

$m + \bar{s} = 4.069$ Antilog = 11,750 cfs plot at 15.9 %

$m - \bar{s} = 3.501$ Antilog = 3,162 cfs plot at 84.1%

$$\text{Approx. skew} = \frac{(3)\ (3.785 - 3.804)}{0.284} = -0.20$$

SECTION IV - DAMAGES

Table of Contents

List of Tables

List of Figures

FLOOD DAMAGES 1/

Surveys. Flood damage surveys were made by stream reaches on each major tributary. Damages on the minor tributaries were determined from studies of representative sample streams. In selecting the sample tributaries to be studied, all minor streams having drainage areas up to 25 square miles were classified by their pertinent major physical characteristics, such as size of drainage area, stream gradient, extent of natural or artificial storage, and the existence of damageable property. This classification of the small tributaries was made for each of the three major soil group areas in the watershed (see Figure 4, Section I).

Table 1 lists the selected sample tributaries by the three major soil groups and shows the percentage of each soil group sampled.

1/ All monetary values are based on long-term projected prices.

Table 1. Sample Tributaries Selected
For Flood Damage Appraisal
From Lower Susquehanna River Watershed

Name	Drainage Area	Percent of Area
	(sq. mi.)	
Soil Group #1 (Shales and Sandstones)		
Dothan Run	1.4	
Unnamed #9 (Ocker Hill School)	2.7	
Newburg Run	5.4	
Cold Springs Run	5.9	
Unnamed #64 (Oakgrove Church)	3.1	
Lower Rauch Creek	4.6	
Swatara Creek	22.7	
Little Swatara Creek	26.9	
Unnamed #102 (Walmers Church)	8.8	
Unnamed #104 (Grantville)	9.4	
Walnut Run	3.1	
Dogwood Run	9.0	
Unnamed #126 (Etters P.O.)	1.7	
Oppossum Creek	14.6	
Unnamed #159 (Welcome School)	6.6	
Unnamed #162 (Dars School)	3.1	
Bermudian Creek	6.5	
Unnamed #185 (York Haven)	1.9	
Fox Run	6.1	
Unnamed #249 (Morgantown)	7.7	
Unnamed #137 (Pine Grove School)	1.2	
Subtotal	152.4	7.9
Soil Group #II (Limestone)		
Green Spring Creek	16.9	
Quittapahillia Creek	21.1	
Unnamed #119 (Stoverdale)	1.2	
Unnamed #229 (Shocks Mill)	3.1	
Strickler Run	6.0	
Unnamed #272 (Schaefferstown)	5.1	
Lilitz Run	14.9	
Unnamed #283 (Monterey)	4.5	
Swarr Run	8.6	
Unnamed #303 (Paradise)	1.0	
Subtotal	82.4	9.2

Table 1 (Cont'd.) Sample Tributaries Selected
For Flood Damage Appraisal
From Lower Susquehanna River Watershed

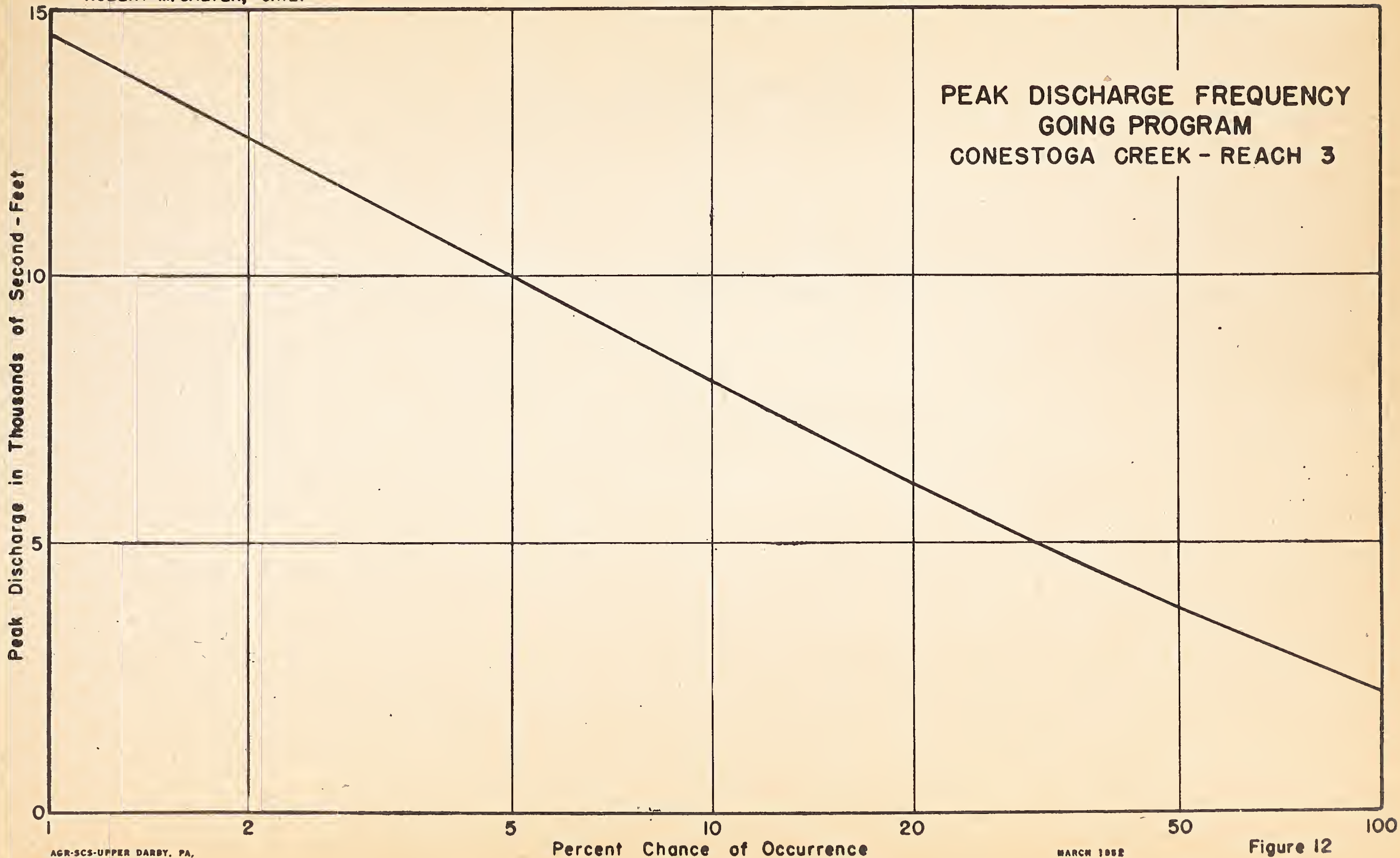
Name	Drainage Area	Percent of Area
	(sq. mi.)	
Soil Group #III (Granites, Gneisses, and Schists)		
South Branch Codorus Creek	4.2	
Beaver Creek #247	6.5	
Unnamed #292 (Highville)	2.3	
Beaver Creek #306	19.6	
North Branch Muddy Creek	16.3	
Unnamed #338 (Peach Bottom)	4.0	
Unnamed #344 (Mill Green)	2.8	
Little Conowingo Creek	6.6	
East Octoraro Creek	10.8	
Bells Run	4.3	
Unnamed #381 (Porter Bridge)	4.1	
Unnamed #384 (New Freedom)	4.0	
Falling Branch	6.4	
Unnamed #411 (Rapidum)	1.8	
Subtotal	93.7	8.3

Average Annual Flood Damages. Flood damages were expressed in terms of average annual values by relating the amount of damages caused by several floods differing in magnitude with their probable chance of occurrence. In order to determine this relationship, in each major tributary reach or sample tributary investigated, damages were appraised by flood stages; flood stages were related to peak discharge, and peak discharge related to probable chance of occurrence. Figures 12, 13, 14, and 15 illustrate these relationships for Conestoga Creek (Reach 3).

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR



AGR-SCS-UPPER DARBY, PA.

MARCH 1952

Figure 12

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR

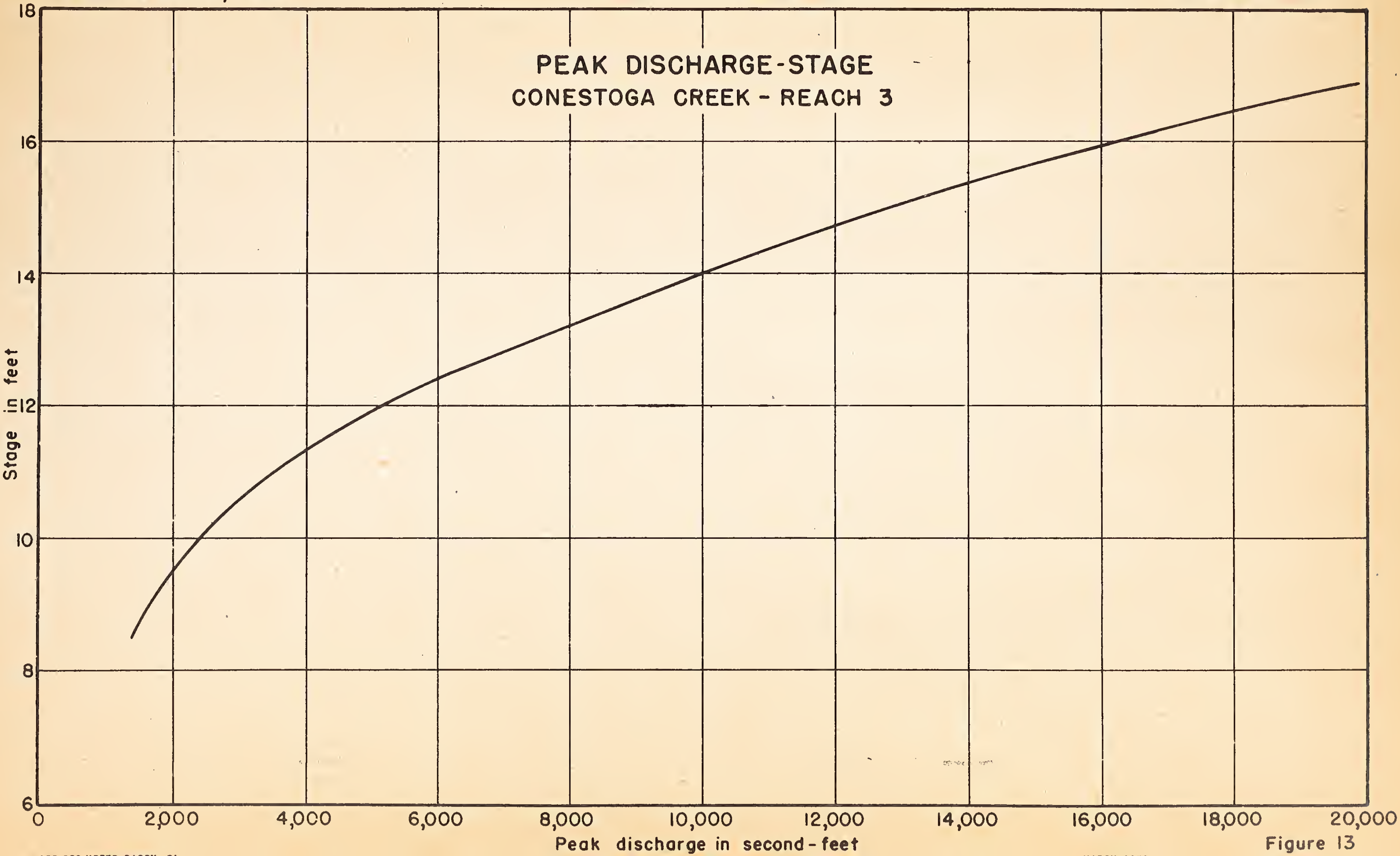


Figure 13

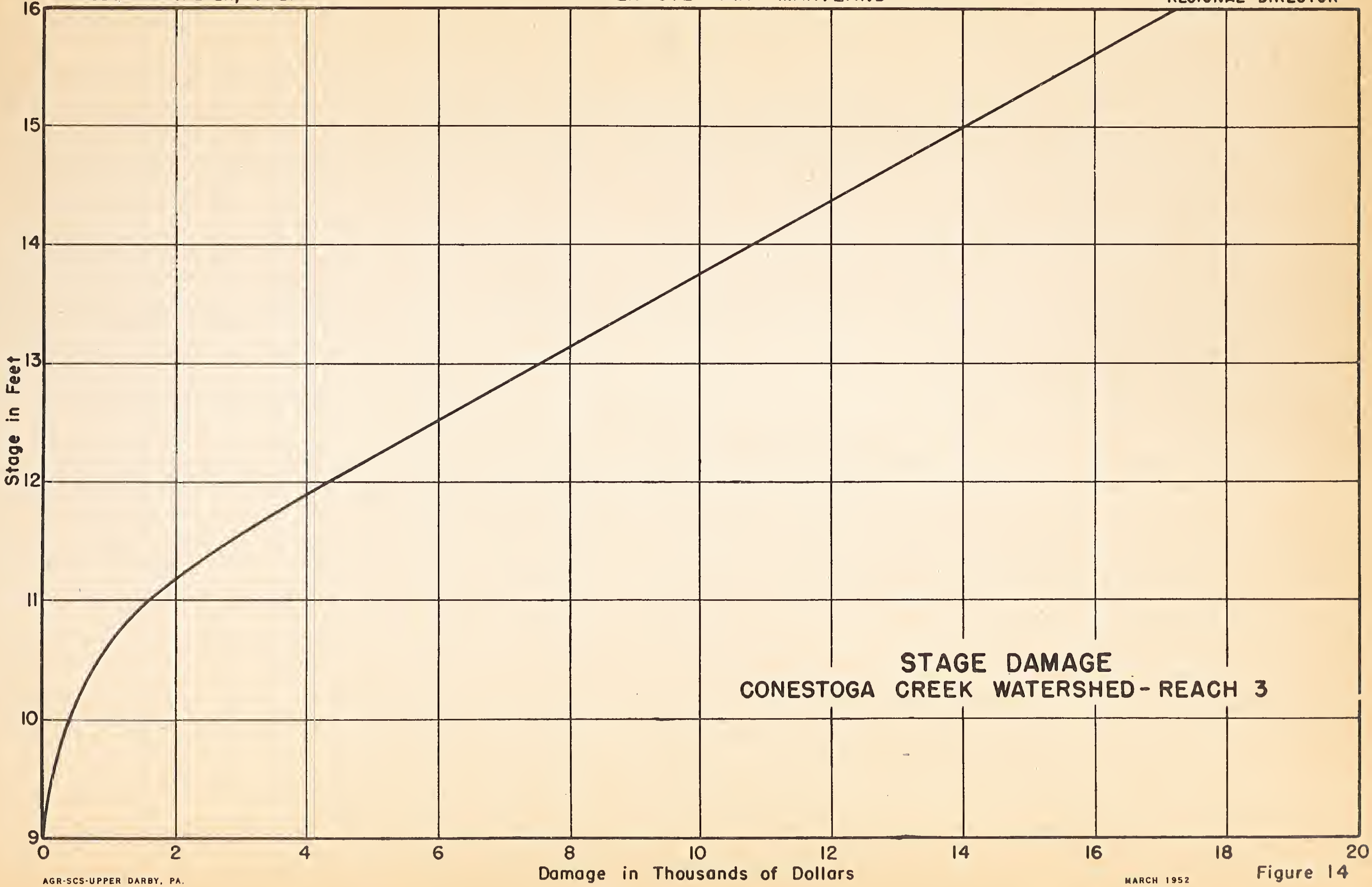
AGR-SCS-UPPER DARBY, PA.

MARCH 1952

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR



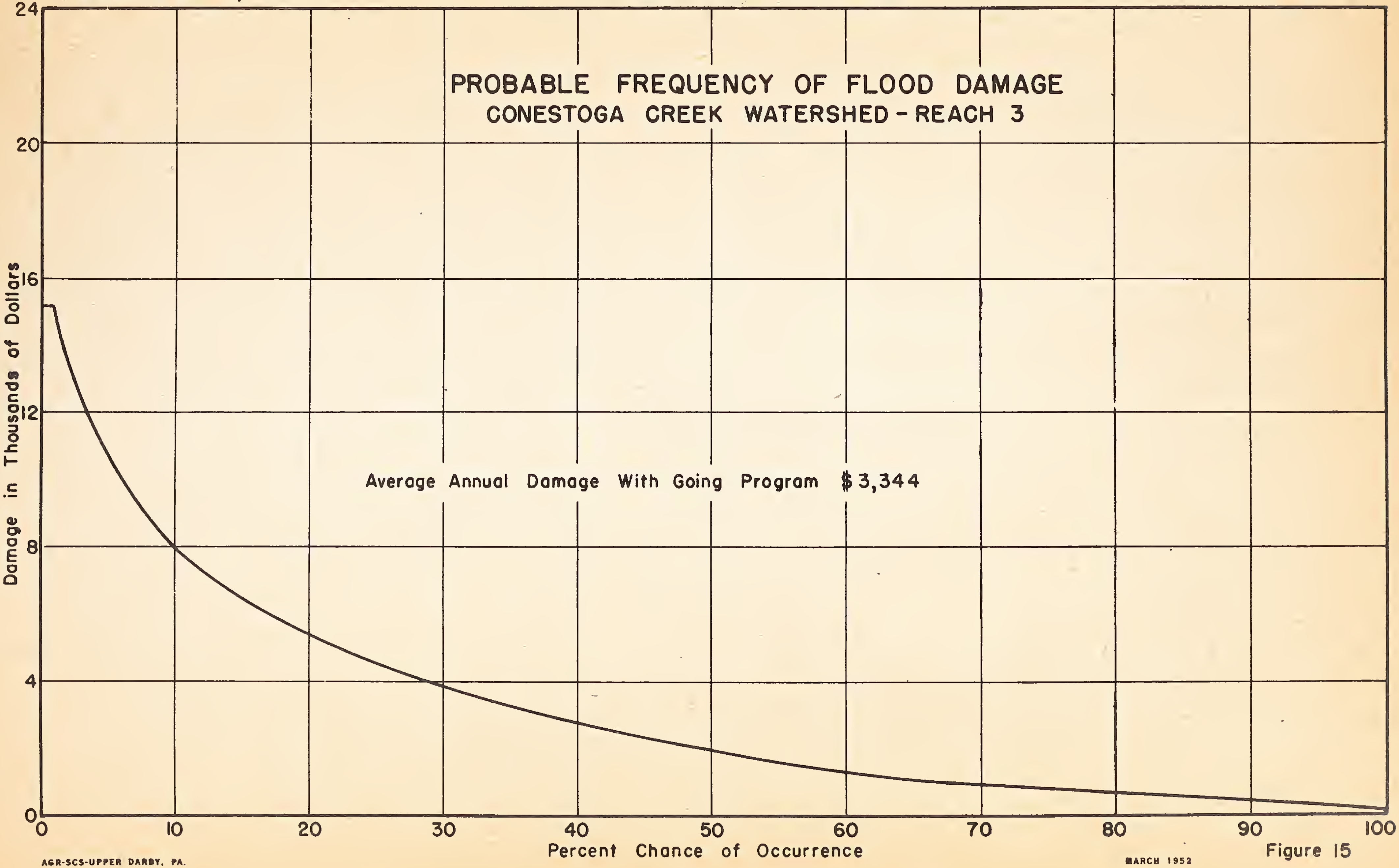
AGR-SCS-UPPER DARBY, PA.
MARCH 1952

Figure 14

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR



AGR-SCS-UPPER DARBY, PA.

MARCH 1952

Figure 15

The amount of damage associated with different flood stages was determined by estimating depth of inundation of the properties damaged and from owners' accounts of damages from experienced flood stages. The relationships of discharge to stage were determined by using cross section and gradient information obtained in the field, in the application of slope-area calculations. The probable chance of occurrence of peak discharges was determined by the method illustrated in Section III. The average annual damage, as computed from Figure 15, is based on all floods whose percent chance of occurrence is less than 100. However, in the computation, it was assumed that the damage would not exceed that shown for the one percent flood. Table 2 shows the estimated average annual flood damages by major and minor tributaries. In computing these values cognizance was taken of the influence of current programs and activities of federal and state agencies on flood damages.

Flood Damage Appraisal. Flood damages are commonly classified as direct and indirect. By direct damage is meant the physical destruction and loss resulting from direct contact with flood water while indirect damage includes all other losses associated with floods. Direct and indirect damages were not separated due to the complexity of their distinction and the difficulty of property owners reporting damages in those terms. However, where it was necessary to appraise indirect damages, they were developed to include such costs as evacuation and reentering premises, erecting temporary shelters and

Table 2. Average Annual Flood Damage by Tributaries
Lower Susquehanna River Watershed

Tributaries	Average Annual Flood Damage (dollars)
Yellow Breeches Creek	1,738
Conodoguinet Creek	10,067
West Conewago Creek	11,978
Codorus Creek	6,057
Fishing Creek	460
Broad Creek	343
Deer Creek	14,218
Swatara Creek	9,298
East Conewago Creek	285
Conestoga Creek	13,741
Peque Creek	5,756
Octoraro Creek	1,335
Conowingo Creek	622
Chickies Creek	143
Little Chickies Creek	174
Kreutz Creek	184
Muddy Creek	2,956
Minor Tributaries in Soil Group I 1/	15,093
Minor Tributaries in Soil Group II 1/	48,120
Minor Tributaries in Soil Group III 1/	81,266
TOTAL	223,834

1/ These damages were developed from studies of sample tributaries.

protection works and higher costs of business operation. Other indirect losses included were the value of loss of use of property during the period of restoration, and loss of labor to the extent that it was not accounted for by emergency work such as evacuating goods, cleaning up, etc. Those damages such as losses in the volume of trade through the reduced flow of goods from the flood area to the channels of trade and industry and through the decreased incomes of the owners of flood plain property were not evaluated. No monetary

value was assigned to intangible losses, such as loss of life, illness, inconvenience, and disruption in social activities.

In appraising damages by stage, flood damages experienced were enumerated and used as the basis of appraisal. In those cases where a property was destroyed and not replaced, the damage was considered non-recurring and was, therefore, not used. In the case of a highway bridge destroyed and replaced by a structure capable of withstanding higher flood flows, the damage was considered non-recurring and modified downward to reflect the damage if the flood flow were to reoccur.

The amount of damage to growing crops varies with the season of inundation. Growing crop damages were, therefore, computed by months to reflect these variations and averaged in accordance with the probable seasonal occurrence of flood flows. The amount of damage to various crops by depth of inundation during different stages of growth was estimated from data collected from farmers who had experienced recent crop damage. Approximately 12,341 acres of crops and 39,894 acres of pasture in the watershed are affected directly by inundation.

SEDIMENT DAMAGES

Damages due to sediment in the Lower Susquehanna Watershed are widespread and significant. Sedimentation results in greater costs of treating water for domestic consumption, higher maintenance costs on highways, loss of storage in reservoirs, and loss of stream channel capacity.

Records on sediment accumulation in Chesapeake Bay go back nearly 100 years. Total accumulation in the Upper Chesapeake Bay, coming almost entirely from the Susquehanna River, is approximately 1 million cubic yards per year. It is estimated that this one million yards of sediment is equal to 500,000 cubic yards of soil in place on the land. Of this total at least 15%, or 75,000 cubic yards, comes from the Lower Susquehanna Watershed. The 75,000 cubic yards are equal to 46.5 acre-feet.

Very little dredging has been necessary in the Upper Chesapeake Bay because of the small amount of water-borne traffic. It is therefore impossible to assign an annual cost for removing the sediment. Should conditions change in the future so as to necessitate regular dredging in Upper Chesapeake Bay, then an annual cost figure would be obtainable.

Three large water power reservoirs are located on the lower main stem of the Lower Susquehanna River. Some accumulation of sediment is taking place in these reservoirs. Part of the sediment is anthracite coal washings which is dredged and used for fuel. The upper and lower reservoirs are channel type pools in which the water level fluctuates due to operation of the gates for water power purposes. Thus far the sedimentation has caused little or no damage because it has occurred only below the low water levels and has not affected storage for power purposes. The largest of these reservoirs has a capacity/watershed ratio of 10.6.

Sediment damages were determined on an annual basis for the various items listed below. In computing these values cognizance was taken of the influence of current programs and activities of federal and state agencies.

Channel Sedimentation. Clearing of stream channels is frequently necessary to prevent damage to bridge piers and abutments or to protect highways and bridge approaches from being washed out. It is estimated that the cost of clearing sediment from stream channels totals $43,092 per year.

Highway Sedimentation. Highway maintenance engineers are confronted with the problem of removing sediment accumulations in highway drainage ditches, culverts, on road surfaces, or in stream channels. A large proportion of this sediment comes from land erosion, directly or indirectly. Costs of removing it were determined on an annual basis by securing cost figures from all state and county highway maintenance engineers and from maintenance workers in representative townships. If this material is not removed, serious damage, due to washouts, is likely to occur. It is estimated that removal of eroded sediment from highway ditches and culverts for all types of roads in the watershed totals $64,000 annually.

Sediment Pollution. Generally speaking, the greater the quantity of sediment in suspension in the water, the greater the cost of chemical treatment to clear water for domestic use. A study was made of the quantities of alum required in relation to turbidity of the water, using as the basis, records supplied by the large municipal water plants taking water directly from surface

supplies. The quantities of alum needed to treat water with greater than 50 parts per million turbidity were considered as caused by eroded sediment. An aggregate yearly cost for alum of approximately $7,700 is estimated. No calculation was made for the cost of cleaning settling basins or of disposing of the sediment taken from the water. The water companies state that no extra help is required and that their regular maintenance crews take care of the extra work.

Reservoir Sedimentation. Water storage reservoirs for domestic water supplies or power installations are numerous in the watershed. In the Pennsylvania portion 42 such reservoirs are described in the files of the State Department of Forests and Waters. Official records for Maryland list but one small reservoir in the Susquehanna drainage in that state. This reservoir serves a boy scout camp, and the water level is varied from low in winter to high in summer. The Pennsylvania listing includes the Conowingo Dam on the main stem of the Susquehanna, which is actually in Maryland but backs water into Pennsylvania.

Reservoirs were grouped and studied according to storage capacity in relation to drainage area. The storage capacity/watershed ratio, as used in this appendix, means the number of acre-feet of storage per square mile of drainage area. Reservoirs with storage capacity/watershed ratios of less than 20 or more than 150 are not considered in this calculation of damages because a watershed treatment program will have little effect on their rate of sedimentation.

Of the total of 42 reservoirs in Pennsylvania, sixteen have storage capacity/watershed ratios of less than 20, and five are over 150. Information available on seven reservoirs was too incomplete to permit grouping them on a capacity/watershed basis. The remaining fourteen reservoirs meet the requirements as to capacity/watershed relationship. Four of these reservoirs are part of a municipal water system and the watersheds above them are already adequately protected, thus leaving ten to be studied.

Rates of sedimentation were well established by studies in the Codorus Creek Watershed, tributary to the Susquehanna River in York County, Pennsylvania. From these rates the total annual sediment accumulation in the ten reservoirs was calculated to be 73.7 acre-feet from a total drainage area of 246.2 square miles. Total original storage capacity of the ten reservoirs was about 13,742 acre-feet, over half of which is in one large reservoir recently put into operation as a water supply for the city of Chester, Pennsylvania. Average annual loss of storage capacity is thus .54%.

Table 3 gives the characteristics of each of the ten reservoirs currently unprotected and losing storage capacity, and shows an estimated total average annual damage of $15,462. This would be reduced to $9,992 by "going" programs.

Table 3. Sediment Damage to Water Supply Reservoirs
Lower Susquehanna River Watershed

Location of Reservoir	Drainage Area	Total Storage (Original)	Annual Loss of Storage Per Sq.Mi. Drainage Area	Total Annual Loss of Storage	Useful Life of Reservoir Without Program 1/	Total Average Annual Damage 2/
	(sq.mi.)	(Acre/ft.)	(Acre/ft.)	(Acre/ft.)	(Years)	(Dollars)
Tributary of South Branch Conewago	1.70	61.2	2.00	3.40	12	2,884
West Branch of Hammer Creek	1.27	55.0	1.00	1.27	29	854
Cabin Creek	2.64	177.4	1.70	4.49	26	2,857
Tributary of West Branch Codorus Creek	2.50	387.4	0.66	1.65	157	3/
Octoraro Creek	139.60	7,650.0	0.13	18.15	282	3/
Paxton Creek	18.10	612.0	0.50	9.05	45	3,228
East Branch of Swatara Creek	18.30	1,101.6	0.50	9.15	81	1,465
Fishing Creek	14.20	948.6	0.50	7.10	90	1,037
East Branch of Codorus Creek	45.00	2,685.5	0.39	17.55	103	1,718
Branch of Codorus Creek at Spring Grove	2.90	63.0	0.66	1.91	22	1,419
TOTAL	246.21	13,741.70		73.72		15,462

1/ Based on loss of two-thirds of original storage capacity.
2/ Calculated by use of sinking fund method, using 2-1/2% interest.
3/ Value not significant.

IV

EROSION DAMAGES

Damage Due to Erosion. Based on numerous research studies, it was estimated that for each inch of topsoil eroded, the average yield decline for cropland would be 6.46%. Studies from the same source indicate the average annual rate of topsoil loss on all cropland is 0.091 surface inches. It is estimated that an annual loss of 0.02 inches of topsoil could be sustained without causing a reduction in crop yields. On this basis the effective rate of soil loss, as far as yield decline is concerned, would be 0.071 inches annually. Application of this annual rate of soil loss to the yield decline data gives an annual yield decline of 0.46%. The average value of the annual crop yields on the present cultivated land is calculated to be $52.52 per acre. The incremental annual loss in value of crop production amounts to $0.24 per acre. This damage is based on the assumption of yield declines; but it may occur through other or combination of other changes, such as increased production costs in an effort to maintain yields or lengthening crop rotation. The value of decreased production was treated as a net loss, inasmuch as reductions in yields causes little or no reduction in costs of raising the crop.[1] The value of the decline in crop production was assumed to represent the erosion damage up to a point of 20% reduction in yields. At this point changes may occur in management practices which

1/ Walter, George H., Agricultural Economics Research, April 1950, Bureau of Agricultural Economics, "One Method for Evaluating Effect of Measures to Prevent Erosion of Topsoil".

would tend toward reduced losses. Based on these factors, the average annual equivalent value of income loss due to erosion was calculated to be \$3.25 per acre of cultivated land or a total of \$3,386,500. This would be reduced to \$2,031,900 by "going" programs.

Rate of Erosion. Rates of soil erosion were determined by using the basic formula:

$E = F \times S^{1.35} \times L^{0.35} \times P^{1.75} \times C$, developed by Musgrave and reported in the Journal of Soil and Water Conservation, Vol. 2, No. 3, July 1947. In the above formula:

E = Soil loss in tons per acre.

F = Soil factor (soil loss per year for continuous cultivation up and down slope).

S = Slope in percent.

L = Length of slope (300').

P = Rainfall - 2-year frequency, 30 min. maximum intensity in inches.

C = Cropping factor - may be product of several separate factors.

Summaries of soil conservation surveys for sizable areas in each of the soil groups were utilized to establish the present land use as related to various slope classes, and to relate the erosion rates shown by the equation to the erosion conditions as revealed by the field surveys. Present annual rates of erosion for the various land uses in the watershed are given in table 4.

Table 4. Calculated Erosion Rate
Lower Susquehanna River Watershed

Land Use	Present Annual Rate of Soil Loss (inches/acres)
Rotation Cropland	.092
Permanent Hay	.016
Pasture	.009
Grazed Woodland	.006
Ungrazed Woodland	.002
Idle and Miscellaneous	.004

Calculation of average annual equivalent value of income loss due to erosion:

0.071 inches = Rate of soil loss effecting yield decline.

6.46 percent = Yield decline per inch of soil loss.

0.46 percent = Annual yield decline (.071 x .0646).

$52.52 = Value of annual crop yields at present.

$ 0.24 = Annual incremental loss in value of crop production (52.52 x .0046).

20 percent = Reduction in yields evaluated.

$10.50 = Ultimate annual loss (52.52 x .20).

44 years = Time required to reach 20 percent reduction in income $(\frac{10.50}{.24})$.

338.41888 = Present value of an increasing annuity at 4% interest.

$3.25 = Value of average annual income loss per acre (.24 x 338.41888 x .04).

SUMMARY OF DAMAGES

A summary of all evaluated damages in the watershed is shown in table 5. In this summary an approximate division of the flood damages, by type, was made. Of the damage due to inundation, about 15.1% of it occurs to highways, 11.1% to industrial establishments, 11.1% to commercial establishments, 37.6% to residences, 12.2% to agriculture, and 12.9% to other properties.

Table 5. Estimated Average Annual Monetary Damage
Lower Susquehanna River Watershed

Type of Damage	Average Annual Damage (dollars)	
Damage Due to Inundation		
Agricultural	27,270	
Non-Agricultural		
Highway	33,833	
Industrial	24,734	
Commercial	24,800	
Residential	84,221	
Other	28,975	
Subtotal		223,834
Damage Due to Sediment		
Channel Sedimentation	43,092	
Highway Sedimentation	64,000	
Water Supply Pollution	7,700	
Reservoir Sedimentation	9,992	
Subtotal		124,784
Damage Due to Erosion		2,031,900
TOTAL AVERAGE ANNUAL DAMAGE		2,380,518

UNEVALUATED DAMAGES

In addition to the damages listed in table 5, there are other damages directly related to flooding, erosion and sedimentation which have not been evaluated in monetary terms.

Unevaluated damages related to flooding:

1. Illness or loss of life.
2. Insecurity of property and income.
3. Disruption of public services.
4. Disturbance of the normal economic and social activity of the population.

Unevaluated damages related to erosion and sediment:

1. Excessive silt in streams which will decrease the stream's capacity to sustain aquatic life. The silt may result in direct interference with the respiration of fish, or the smothering of fish food organisms on the bottom.
2. Silt blanketing the stream channels which adversely affects the rate of reaeration in a stream and its ability to assimilate discharges of municipal and industrial sewage.
3. A high silt content and turbidity in streams from which industries obtain processing or cooling waters directly.
4. A detrimental effect on the recreational values in the watershed.

SECTION V - PROGRAM

Table of Contents

List of Tables

DETERMINATION OF NEEDS

Land Treatment. Areas of openland devoted to different uses were determined from the U. S. Agricultural Census. Information was collected by minor civil divisions, on acreages of total crop, pasture, other open farmland, and grazed forest land, in addition to the areas of specific crops. Figures for land use in minor civil divisions were combined to give areas by subwatersheds, counties, states, and by the three major soil group areas of the watershed. Numbers of livestock, especially beef and dairy cattle, were determined from the U. S. Agricultural Census and used as a guide in calculating the acreage of pasture required.

Twelve soil conservation districts are wholly or partly within the Lower Susquehanna River Watershed and conservation plans have been prepared for more than 4,000 farms in these districts. These planned farms were classified as to size and major farm enterprise within each of the three major soil group areas and approximately 10 percent were selected as samples from which to determine the openland needs of the watershed.

Land use adjustments as determined from the sample farms were applied to the entire area in the watershed by reference to the present uses of land shown by the 1950 Agricultural Census. Land conversions on the sample farms were based on land use capabilities and the needs of the individual landowner or operator.

The needed land use changes involve principally, reductions in acreages of clean tilled and grain crops, poor pasture, grazed

forest land and idle land, and increases in acreages of hay, good pasture and good forest land. Actual changes in acreages of each land use, while dependent on the capability of the land, will also be influenced by such factors as location on the farm, field arrangement and local economic considerations. These adjustments will provide substantial reductions in flood, sediment and erosion damage.

The types and amounts of conservation measures and practices planned for cropland on the sample farms depended on the capability of the land and its future use. Total needs of the watershed were calculated by projecting the planned measures and practices from sample farms to the appropriate future land use acreages for the watershed.

The kind and amount of needed forest land measures were determined from a forest inventory of the watershed. This inventory was made by analyzing aerial photographs, with field checks to substantiate the photographic analysis. It revealed present conditions and indicated the steps necessary to remedy them. Local, state, and federal agencies contributed information and advice on the development of the watershed needs. These data were supplemented by a special field survey of sample watersheds representative of the three major soil group areas in the watershed.

The need for public acquisition of land in the watershed was determined by (1) the importance of such land for flood and sediment control, and (2) the fact that such land is submarginal for private use or has some other characteristic which makes the public interest paramount.

Additional Measures. The needs of the watershed relative to such flood control measures as water retarding structures, channel improvement, and diking were determined as follows.

For minor tributaries, up to approximately 25 square miles in size, studies were made of the same sample tributaries used for flood damage appraisal. Information previously collected on each sample tributary supplied data on the frequency of occurrence of floods, and discharge-frequency relationships applicable to the area. From these data additional measures, primarily for flood control, were planned to reduce damage within the tributary drainage. A detailed economic evaluation was made of each control measure and those measures not showing benefits in excess of costs were eliminated. Measures showing benefits in excess of costs were used in the projection to areas represented by the sample tributary. This projection provided the data on total needs for the minor tributaries.

To determine the need for these measures on the major tributaries of the watershed, a detailed study was made of each stream reach for which the damage appraisal had indicated significant flood damages. The planning of these measures was based on the effect they will have on reducing flood damages. Costs and benefits of the individual measures were determined and only those measures which showed benefits in excess of costs were included in the needs.

Table 1 indicates the needed land use adjustments. Table 2 lists the practices and measures needed in the Lower Susquehanna Watershed.

Table 1. Needed Land Use Adjustments
Lower Susquehanna River Watershed

Present Land Use		Future Land Use							
		Cultivated	Perm. Hay	Orchard	Pasture	Forest Land Grazed	Forest Land Ungrazed	Wildlife	Miscel-laneous
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Farmland:									
Cultivated	1,042,000	908,800	61,500	1,000	59,800	-	9,200	1,000	700
Perm. Hay	9,400	200	8,400	-	800	-	-	-	-
Orchard	38,100	600	300	30,500	2,800	700	3,100	100	-
Pasture	241,700	3,400	600	-	235,300	100	1,400	200	700
Grazed Woods	19,700	-	-	-	3,700	1,300	14,700	-	-
Ungrazed Woods	196,300	-	300	-	2,100	-	193,500	400	-
Wildlife	1,800	-	-	-	-	-	-	1,800	-
Idle & Misc.	200,500	11,700	2,400	100	26,300	-	16,100	2,100	141,800
Total Farmland	1,749,500	924,700	73,500	31,600	330,800	2,100	238,000	5,600	143,200
Non-Farmland:									
Forestland	469,400	-	-	-	-	-	469,400	-	-
Openland	128,600	-	-	-	-	-	22,200	20,100	86,300
Urban, Roads, etc.	176,700	-	-	-	-	-	-	-	176,700
Total Non-Farmland	774,700	-	-	-	-	-	491,600	20,100	263,000
WATERSHED TOTAL	2,524,200	924,700	73,500	31,600	330,800	2,100	729,600	25,700	406,200

Table 2. Needed Practices and Measures
Lower Susquehanna River Watershed

Practice	Unit	Quantity
Land Treatment Practices and Measures:		
Contour Strip Cropping	Acre	933,900
Cover Cropping	"	84,700
Diversions and Terraces	Mile	3,178
Establishing Perennial Hay	Acre	64,200
Outlets and Waterways	"	5,600
Pasture Improvement	"	117,200
Pasture Management	"	242,800
Pasture Seeding	"	114,700
Contour Furrowing	"	8,600
Streambank Erosion Control	Mile	68
Erosion Control Structures	No.	14,000
Wildlife Area Development	Acre	38,700
Improved Forest Management	"	731,700
Forest Planting	Acre	38,200
Public Land Acquisition	"	5,000
Additional Measures:		
Diking	Mile	1.7
Stream Channel Improvement	"	104

CURRENT PROGRAMS OF THE U. S. DEPARTMENT OF AGRICULTURE

Four agencies in the Department--Production and Marketing Administration, Forest Service, Extension Service, and Soil Conservation Service--are currently engaged in programs which are primarily designed to maintain soil resources and improved crop and timber yields but which do provide some flood control benefits.

The Production and Marketing Administration furnishes direct aids to individual farm owners for the application of many soil and water conservation measures and practices, such as the improvement of hay and pasture lands through lime and fertilizer applications, establishment of hay and pasture, construction of diversions and terraces, strip cropping, construction of grassed waterways, the use of cover crops or mulching, tree planting, protection of forest land from grazing, and timber stand improvement.

The Forest Service cooperates with the states in promoting sound forestry practices. Through the cooperative Forest Management Act, technical services in forest land management are furnished to forest land owners. Under the provisions of the Clarke-McNary Act financial assistance is furnished to states for fire protection and for production of tree seedlings to be distributed to land owners at low cost. The present fire control program is considered adequate for the watershed.

The Extension Service is cooperating with the State Extension Services which, through their county agricultural agents and extension specialists, are currently conducting an educational

program in the counties of the watershed which is helping to increase the application of various land treatment practices and measures.

The Soil Conservation Service is furnishing technical services to soil conservation districts for the planning and installation of soil and water conservation practices and measures. Limited amounts of tree and shrub planting stock are furnished to districts.

It was assumed that the current rate of establishment by these agencies would continue during the 20-year installation period of this program in estimating the accomplishments of "going" Departmental programs.

A portion of the needed land conversions shown in table 1 will be accomplished by the current programs. It is estimated that the area in cropland will decrease about 9,600 acres and that idle and miscellaneous openland will decrease about 16,300 acres. The area improved for wildlife cover will increase about 3,800 acres, pasture will increase about 14,300 acres, and forest land will increase by 7,800 acres.

The Department of Agriculture is now expending $414,240 annually in the Lower Susquehanna River Watershed to carry out these activities.

RECOMMENDED PROGRAM

The recommended program includes the intensification, acceleration, and adaptation of certain activities under current programs of the U. S. Department of Agriculture, and additional measures not now regularly installed but considered necessary to complete a balanced runoff and waterflow retardation and erosion control program for the watershed. The recommended program is deemed

of primary importance to the objective of the flood control act and does not include measures or practices for the primary purpose of increasing production. For example, items such as: the application of fertilizer for production only; farm water supply and distribution systems exclusively for the purpose of livestock and domestic use; drainage and irrigation for increased production; tree planting or timber stand improvement for timber production only; and the installation of recreational facilities are not included as part of the recommended program.

The quantities of the various measures and practices in the recommended program are the difference between the total watershed needs and the estimated 20-year accomplishments of "going" Departmental programs, except that the recommended program for forest lands has been set at those levels that it is estimated can be achieved without new legislation providing for public control of forest practices on privately owned forest lands.

The recommended openland program includes land use conversions and certain practices and measures. The land use changes involve decreases in acreages of all crops except tobacco which remains the same, and increases in land devoted to perennial hay and pasture land. The proposed increase in grassland is in keeping with current trends. Recommended future crop, hay, and pasture acreages permit use of the land within its capability and are sufficient to satisfy the economic needs of the farms in the watersheds. The land use changes and conservation practices and measures, as

recommended for openland, will reduce runoff and sedimentation which is a public benefit; and will conserve soil and water which will result in increased income to landowners.

The recommended program for forest land provides for an increase in forest area through the conversion of openland to forest; for the application of improved forest management and watershed protection measures on public and privately owned forest land; and for public acquisition of approximately 5,000 acres of submarginal land which is vital for watershed protection or has some other characteristic that makes the public interest paramount.

One or more of the recommended measures will be installed on all forest land except approximately 9,900 acres contained in the Indiantown Gap Military Reservation. Installation of the improved forest management and watershed protection measures and practices will increase the density of stand stocking, improve stand composition, and correct present unsatisfactory watershed conditions in the logging road and trail system. Hydrologic condition of the forest area will improve as the average humus depths and the percentage of organic material in the soil profile increases. These improvements in forest soil conditions, together with the corrective action applied on logging roads and skid trails, will reduce surface runoff and stabilize forest soils.

The recommended program is shown in table 3.

Table 3. Recommended Program
Lower Susquehanna River Watershed

Practice	Unit	Quantity
Land Treatment Practices and Measures:		
Contour Strip Cropping	Acre	566,700
Diversions and Terraces	Mile	2,600
Establishing Perennial Hay	Acre	30,800
Outlets and Waterways	Acre	2,300
Pasture Management	Acre	109,600
Contour Furrowing	Acre	6,000
Streambank Erosion Control	Mile	65
Erosion Control Structures	No.	6,900
Wildlife Area Development	Acre	35,400
Improved Forest Management	Acre	721,800
Forest Planting	Acre	26,900
Public Land Acquisition	Acre	5,000
Additional Measures:		
Diking	Mile	1.7
Stream Channel Improvement	Mile	104

Following is a description of the individual practices and measures.

Contour Strip Cropping. This measure is the growing of hay or other close growing, soil conserving crops in alternate contour strips with clean tilled or soil depleting crops. Such a measure maintains at least half of the strip cropped fields in hay or close growing crops which will filter out eroded material and reduce sedimentation downstream. Contour cultivation, which is included with contour strip cropping in this report, is used to protect gently sloping land or small fields where strip cropping is not feasible. Contour cultivation and contour strip cropping reduce the rate and amount of runoff by increasing infiltration rates and by providing temporary surface storage. The removal of hedgerows or other obstructions is necessary on many farms for proper installation of contour strip cropping.

Diversions and Terraces. Diversions and terraces are grouped as one measure since they have the same general function, intercepting surface runoff and carrying it across slopes in designed channels. Diversions are normally kept in perennial hay, while terraces are used for the same crop as the contiguous land. Both diversions and terraces are used to supplement the vegetative control effect of strip cropping and contour cultivation on long slopes where concentration

of runoff would cause gully erosion. The removal of hedgerows and other obstructions is often necessary for the installation of this measure.

<u>Establishing Perennial Hay</u>. Vegetative cover consisting of long lived legumes and grasses suitable for hay is recommended for those areas where clean tilled crops cannot be safely grown in rotation. Reseeding of the hay mixture will be done at infrequent intervals with as little cultivation of the land as possible. Perennial hay is also recommended for filter strips to protect diversions. Runoff will be reduced and erosion will be largely eliminated by adequate hay cover on present critical areas.

<u>Outlets and Waterways</u>. Natural drainage ways are used wherever possible for disposing of water from diversions and terraces. They are usually stabilized and protected by permanent grass cover. Where grass will not provide a safe cover, additional protective measures, such as drop structures, chutes, or flumes will be used. These mechanical measures are included under another heading. Properly constructed and protected outlets and waterways will appreciably reduce gully erosion and sedimentation damage.

<u>Pasture Management</u>. The objective of pasture management is the maintenance of adequate vegetative cover on land used for pasture to reduce erosion and runoff. Mowing to control

weeds and remove mature grasses, scattering of droppings, and regulating the intensity of grazing are essential to good pasture management. Additional fencing is usually required for adequate control of grazing. Certain areas of pasture are rough or are partially covered by trees or brush. Where necessary, these obstructions will be removed.

Contour Furrowing. Level furrows or small level terraces with no outlets are used for storage of water on pastured slopes where the vegetative cover is inadequate. On shallow shale soils, chiseling the subsoil on the contour will be substituted for contour furrows. Temporary storage, equivalent to one-half inch of runoff from the area treated, is provided by this practice.

Streambank Erosion Control. Eroding streambanks on small tributary streams cause sedimentation damage downstream and loss of flood plain land adjacent to the streams. Erosion control for such banks involves sloping the banks and protecting them by mechanical means such as riprap or by suitable vegetation.

Erosion Control Structures. Included in this classification are such small structures as drop inlets, flumes, and culverts. These structures are used to protect waterways, outlets or other water disposal channels from gullying or other types of erosion.

Wildlife Area Development. Small, irregular and inaccessible areas, as well as narrow strips of land along field borders often left idle, are serious erosion problems and are usually runoff and sediment sources. Approximately 35,400 acres will be stabilized by planting and protection from grazing. The stabilization of these areas will reduce erosion and sediment production and provide wildlife cover.

Improved Forest Management. The program will consist of assistance, instruction and demonstration in the proper methods of managing and harvesting the timber crop to minimize destructive logging practices and to maintain good forest cover--thus improving both the hydrologic condition and the timber yield of forest lands. Items which will be included are: assistance in the preparation of management plans; assistance in the selection of trees to be harvested--to improve both stand quality and stocking; advice and assistance in the utilization and marketing of forest products to give the forest landowner the best possible financial return for his efforts; advice and assistance on the location and construction of logging roads to insure minimum disturbance of hydrologic conditions; assistance in correcting unsatisfactory drainage conditions on present logging road and trail systems--including installation of water spreading devices to distribute runoff, gully checks, additional drainage ditches to remove runoff from abandoned eroding roads, and

reseeding of bare eroding areas; assistance in protecting forest areas from livestock grazing which compacts the soil and destroys tree reproduction.

Forest management is needed on the entire 721,800 acres of manageable forest land in the watershed. However, not all of the measures listed above will be needed on every acre. The following amounts are recommended:

Management plans.	420,000	acres
Timber marking.	310,750	"
Utilization and marketing service . .	638,500	"
Logging road stabilization.	498,400	"
Protection from grazing	12,000	"

Forest Planting. Approximately 26,900 acres of openland will be planted to trees. The remaining acreage, recommended for conversion, will be allowed to restock naturally because it is favorably located with respect to seed sources.

Public Land Acquisition. Approximately 5,000 acres of land in the strip mining region of the Lower Susquehanna Watershed will be purchased by public agencies for parks, game lands, or forests. These areas are in western Schuylkill County and northern Lebanon County. The land to be purchased contributes heavily to flood water and sediment flow and its acquisition is necessary to good flood control

administration and watershed protection. Much of the area needs stabilization and revegetation following strip mining operations.

<u>Diking</u>. This measure provides protection from inundation of valuable bottomland and such improvements as highways and farm buildings where limitation of rights-of-ways and gradients prohibits the use of channel improvement. The dikes will be of earth fill construction with side slopes of $1\frac{1}{2}:1$, and generally will not exceed five feet in height. Floodways will be provided to safely carry flood discharges of design frequency.

<u>Stream Channel Improvement</u>. The objectives of this measure are to reduce the damages resulting from inundation of valuable bottomland, provide outlets for drainage works, and furnish flood protection for high value improvements, such as highways, railroads, bridges and farm buildings. To accomplish these objectives the discharge capacity of stream channels will be increased by the removal of debris and sediment deposits, clearing and snagging, realignment and bank sloping.

SECTION VI - PROGRAM APPRAISAL

Table of Contents

List of Tables

List of Tables (Con'd.)

List of Figures

PROGRAM APPRAISAL 1/

The primary effects of the recommended program toward reducing flood, sediment, and erosion damages were evaluated separately in monetary terms. Other benefits, monetarily evaluated, were land enhancement, increases in cropland, pasture and forest production and decreases in cost of production due to the recommended changes in land management.

It is expected that when the recommended program is fully effective, the reduction in flood, sediment, and erosion damages for the watershed will be 17.6 percent, 44.5 percent, and 100 percent respectively. Other benefits due to decreasing the hazards of floods and sedimentation, but not experienced in monetary terms, are savings in lives and mental distress, increase in property values, decrease in loss of fish and wildlife, increased low waterflow of streams resulting in pollution abatement, water conservation, fewer interruptions in community functions, and others of a more or less intangible nature.

Substantial land enhancement benefits will accrue to landowners due to the decreased flood hazard which will allow more intensive use of the land.

Changes in land use and land management as recommended, will increase cropland, pasture, and forest production, and will in some cases, decrease the cost of production. They will also control erosion

1/ All estimates of costs and benefits are based on projected long-term prices.

to the point where present rates of production can be maintained without increasing the cost of that production. These benefits, to the extent that they accrue to the landowners and operators, have been evaluated in monetary terms. From these private benefits, however, the public will gain by way of maintenance of natural resources and public revenues, a constant supply of cropland, pasture, and forest products, improved recreational facilities, and increases in fish and wildlife throughout the watershed.

EFFECT OF LAND TREATMENT

Flood Damage Reduction

Evaluation Procedure. Reductions in flood damages expected from application of the recommended program were calculated for each stream on which damages were evaluated. A summary of the present average annual flood damages and the estimated reductions is shown in Table 1. The reduction in average annual damages is equivalent to the difference in average annual damages sustained with going programs fully effective and the estimated average annual damages after the application of the recommended program.

The evaluated damages shown do not include those which are expected to be controlled by existing projects or projects under construction by the Department of the Army, Corps of Engineers. The method used in deriving flood reductions is illustrated by the following discussion of its application to Reach 3 of Conestoga Creek.

Table 1. Average Annual Flood Damages and Benefits
Projected Long Term Prices
Lower Susquehanna River Watershed

Tributaries	Average Annual Damage With			Flood Damage Reduction From		
	Going Program	Land Treatment	Additional Measures	Land Treatment	Additional Measures	Total
	(dollars)	(dollars)	(dollars)			
Yellow Breeches Creek	1,738	1,451	1,451	287	-	287
Conodoquinet Creek	10,067	8,521	8,415	1,546	106	1,652
West Conewago Creek	11,978	9,832	9,832	2,146	-	2,146
Codorus Creek	6,057	5,349	5,280	708	69	777
Fishing Creek	460	415	415	45	-	45
Broad Creek	343	291	291	52	-	52
Deer Creek	14,218	12,171	12,171	2,047	-	2,047
Swatara Creek	9,298	7,885	7,885	1,413	-	1,413
East Conewago Creek	285	279	279	6	-	6
Conestoga Creek	13,741	11,420	11,420	2,321	-	2,321
Peque Creek	5,756	4,951	4,951	805	-	805
Octoraro Creek	1,335	1,082	1,082	253	-	253
Conowingo Creek	622	560	560	62	-	62
Chickies Creek	143	115	115	28	-	28
Little Chickies Creek	174	137	137	37	-	37
Kreutz Creek	184	156	156	28	-	28
Muddy Creek	2,956	2,485	2,485	471	-	471
Miscellaneous Tributaries in Soil Group I	15,093	13,373	12,587	1,720	786	2,506
Miscellaneous Tributaries in Soil Group II	48,120	39,361	39,361	8,759	-	8,759
Miscellaneous Tributaries in Soil Group III	81,266	71,532	65,657	9,734	5,875	15,609
TOTAL	223,834	191,366	184,530	32,468	6,836	39,304

Sample Appraisal Method. This tributary of the main stream has a drainage area of 117.8 square miles at Reach 3. Flood damage along the creek in this reach includes industrial, agricultural and highway damages that are typical. Damage frequency relations representing going program conditions and conditions with the recommended land treatment program in effect are shown in Figure 17. The upper graph in the figure shows damage-frequency relations with the going program, while the lower graph shows this relationship with the recommended land treatment program in effect. These graphs showing damage-frequency relationships, were developed by first relating flood damage to flood stage. Stage was then related to discharge and discharge was in turn related to frequency. Discharge-frequency relationships are shown in Figure 16. The method of deriving discharge-frequency curves is shown in Section IV of this Appendix.

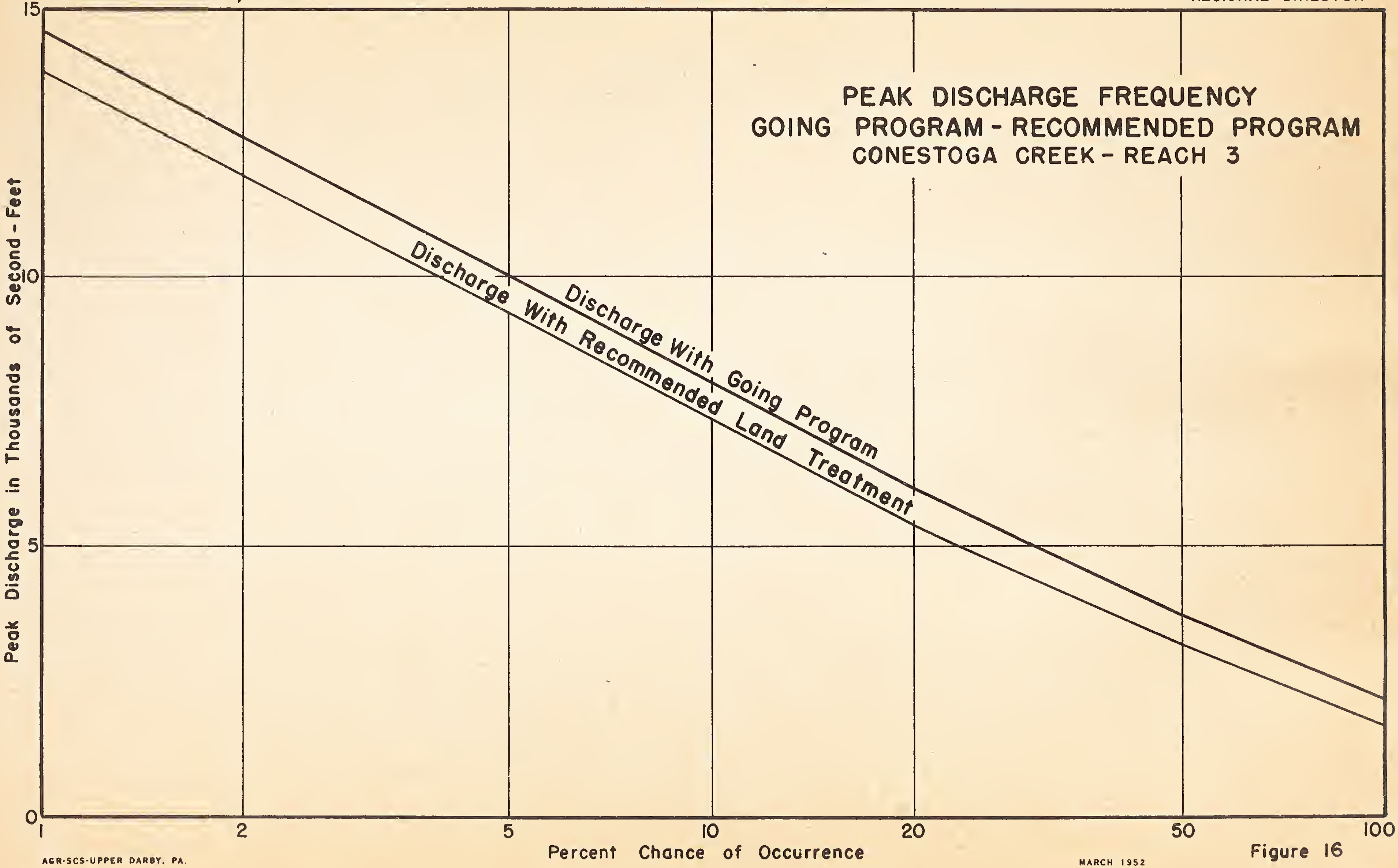
The flood reduction benefit is computed from the graphs in Figure 17. In the case of reach 3 of Conestoga Creek the average annual damage with the going program is $3,344 and with the recommended land treatment program is $2,500. The annual benefit attributable to the recommended program is the difference between the two amounts or $844.

Summary of Benefits. Using the above procedure, the average annual flood damage reduction for the watershed attributable to the recommended land treatment program is $32,468. Of this amount, $3,955 is reduction in agricultural damages and $28,513 is reduction of non-agricultural damages.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR



AGR-SCS-UPPER DARBY, PA.

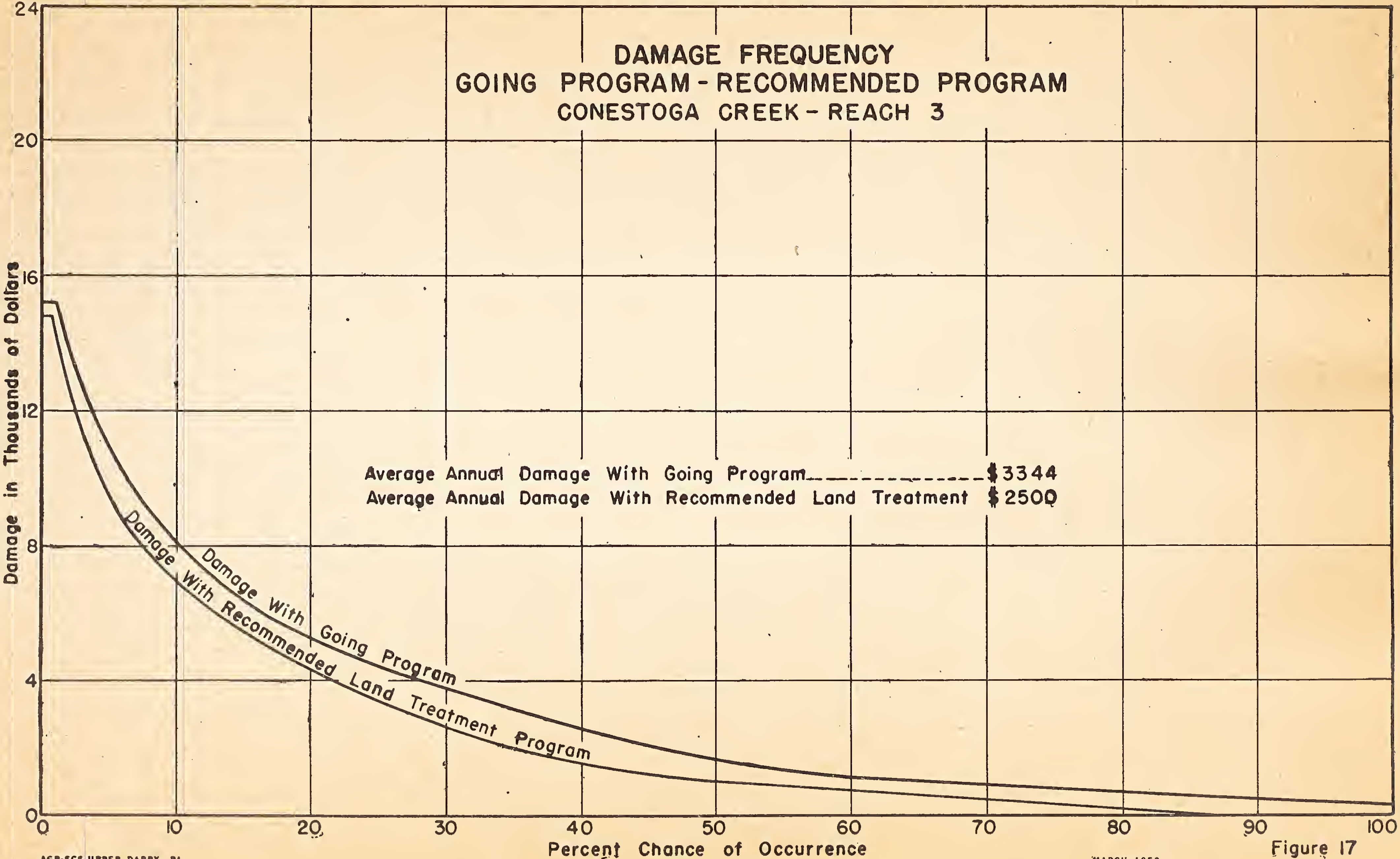
MARCH 1952

Figure 16

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER, CHIEF

LOWER SUSQUEHANNA RIVER WATERSHED
PENNSYLVANIA - MARYLAND

NORTHEASTERN REGION
AUSTIN L. PATRICK
REGIONAL DIRECTOR



AGR-SCS UPPER DARBY, PA.

MARCH 1952

Figure 17

Sediment Damage Reduction.

Installation of the recommended land treatment program will provide sediment reduction benefits from several sources. Certain of the recommended measures which control erosion will substantially reduce the number of present active sediment source areas.

Channel Dredging. Sediment deposits in stream channels which cause highway, bridge, and road grade damage will be reduced approximately 40 percent by the installation of the needed land treatment measures. This will reduce annual channel dredging costs $20,520. Of this amount, 60 percent or $12,312, is attributable to the recommended program.

Highway Maintenance. Sediment deposits in highway ditches, culverts, and on road surfaces will be reduced approximately 60 percent by the soil stabilizing effect of the land treatment measures. This will effect a reduction of $50,100 in annual highway maintenance costs. Of this amount, approximately 60 percent or $30,060 is attributable to the recommended program.

Water Treatment. The sediment content of domestic water supplies will be reduced enough to effect a 75 percent reduction in expenditures for filtration. This amounts to a reduction of $8,250 in annual water treatment costs. Of this amount, 60 percent or $4,950 is attributable to the land treatment measures included in the recommended program.

Reservoir Siltation. Reservoirs are expected to be replaced

prior to any significant loss of services resulting from storage loss through sediment deposition. In determining the useful life of reservoirs under present rates of storage loss, it was estimated that after two-thirds of the original capacity is lost, the reservoirs will be inadequate to provide a dependable supply of water and will be replaced. The measures planned will reduce the rate of storage loss 67 percent through reducing the rate of erosion. This beneficial effect will triple the useful life of the reservoirs. The original cost of constructing the reservoirs and the cost of replacing the storage lost was not available. The cost of replacement was estimated for each reservoir on the basis of average costs of providing an acre-foot of storage. The estimated cost of replacement ranged from $270 to $650 per acre-foot, depending on the characteristics of each reservoir. Inasmuch as the reservoirs represent public investments, 2-1/2 percent interest rate was used in the evaluation. A sample calculation is presented below:

Water Supply Reservoir - Located on West Branch of Hammer Creek

Useful Life of Reservoir Without Program		29 Years
Useful Life of Reservoir With Program		87 Years
Replacement Cost of Capacity Lost	$35,750	
Average Annual Damage Without Program (35,750 x .0238913 1/)	$ 854	
Average Annual Damage With Program (35,750 x .0033025 2/)	$ 118	
Average Annual Benefit (854 - 118)	$ 736	

1/ Sinking fund factor for 29 years at 2-1/2 percent interest.

2/ Sinking fund factor for 87 years at 2-1/2 percent interest.

The installation of the total land treatment measures needed will reduce the loss of reservoir storage capacity 67%, amounting to an average annual benefit of $13,674 (Table 2). Of this amount, 60%, or $8,204, is attributable to the recommended program.

Table 2. Value of Reduction of Sediment Damage to Water Supply Reservoirs
Lower Susquehanna River Watershed

Location of Reservoir	Useful Life Without Program	Useful Life With Program	Replacement Cost	Av. Annual Damage 1/ Without Program	Av. Annual Damage 1/ With Program	Average Annual Benefit
	(years)	(years)	(dollars)	(dollars)	(dollars)	(dollars)
Tributary of South Branch Conewago	12	36	39,780	2,884	694	2,190
West Branch of Hammer Creek	29	87	35,750	854	118	736
Cabin Creek	26	78	102,892	2,857	439	2,418
Tributary of West Branch Codorus Creek	157	471	197,574	2/	-	-
Octoraro Creek	282	846	2,065,500	2/	-	-
Paxton Creek	45	135	263,160	3,228	243	2,985
East Branch of Swatara Creek	81	243	374,544	1,465	23	1,442
Fishing Creek	90	270	341,496	1,037	11	1,026
East Branch of Codorus Creek	103	309	805,650	1,718	10	1,708
Branch of Codorus Creek at Spring Grove	22	66	40,950	1,419	250	1,169
TOTAL				15,462	1,788	13,674

1/ Calculated by use of sinking fund method, using 2-1/2% interest rate.
2/ Value not significant.

Erosion Damage Reduction

The total land treatment program needed in the watershed will reduce soil losses sufficiently to prevent future losses in income from soil erosion on agricultural land. Therefore, the benefit from the total land treatment program would be equal to the present average annual damage from soil erosion amounting to $3,386,500. It is estimated that 60 percent of this benefit or $2,031,900 is attributable to the recommended land treatment program.

EFFECT OF ADDITIONAL MEASURES

Appraisal Procedure.

Benefits from additional measures were computed separately and include either reductions in flood damage over and above that attained by the land treatment measures or land enhancement values through increased crop and pasture production.

Land enhancement is used as a means of evaluating benefits on many low gradient streams, where frequent flooding and sedimentation occur. Flood damage in these areas is relatively low because of the present limited use of the land. However, benefits would be considerable if the frequent flooding and sedimentation were prevented. This situation occurs in the upper reaches of some of the sample tributaries studied. Extent of damage, methods of control, costs, and benefits were studied in these areas. Benefits due to the enhancement of the agricultural land by way of channel improvement, prevention

of frequent inundation, and reduction of sedimentation were determined as the difference in the net value of crop and pasture production under present conditions, and under conditions prevailing with the corrective measures installed.

Items used in computing the annual value of land enhancement are shown in Table 3. Costs of crop production were estimated to include such items as seed, fertilizer, land preparation, cultivation, harvest, and all labor. Costs of land clearing, farm ditching, etc., were included as project costs. No reduction in flood damage to growing crops in these areas was claimed. In estimating crop yields for both present and future conditions, the probable extent of flood damage was considered.

Table 3. Values Used in Evaluating Land Enhancement Attributable to Additional Measures Lower Susquehanna River Watershed

Crop	Yield	Value of Production Per Acre (dollars)	Cost of Production Per Acre (dollars)	Net Value of Production Per Acre (dollars)
Corn	65 Bu.	94.25	41.90	52.35
Wheat	23 Bu.	34.96	28.30	6.66
Hay	1.5 Ton	27.90	19.55	8.35
Poor Pasture	30 A.U./Day 1/	4.80	2.50	2.30
Good Pasture	90 A.U./Day	14.40	5.60	8.80

1/ Animal Units grazing per day.

Flood damage reduction benefits accruing to the additional measures includes reduced damage to urban and commercial installations. These benefits were calculated by estimating the reduction

in flood stages and/or frequency of flooding resulting from establishment of these measures.

Diking.

This measure is recommended where the present channel condition and capacity are inadequate and limitations of gradient and right-of-way prohibit excavation to the required capacity. The effect of diking is to contain within flood ways the flow which would normally be outside of the existing channel. An example of the computation of the effect of this measure on the South Branch of Codorus Creek follows:

Construction of 125 feet of 5-foot dike will protect the damage point in question against backwater from most out-of-bank flows. The frequency of inundation will be reduced from an annual occurrence to once in more than 100 years. The revised damage-frequency curve for the point shows a reduction of $78.17 in annual damages.

The estimated installation cost of this 125-feet of dike is $858, of which $644 is public and $214 is private. Expressed in annual terms, using 2-1/2 and 4 percent rates of interest respectively, the cost is $24.66. It is estimated that the annual maintenance cost will be $31.50, making a total annual cost of $56.16. Thus the benefit-cost ratio of this section of diking is 1.4 to 1.

Using the above method, the amount of diking needed for the whole watershed was evaluated. An annual benefit from the recommended diking amounting to $3,113 is included in Table 1. This benefit is derived entirely from reduced inundation damage.

Stream Channel Improvement.

This measure provides for the improvement of stream channels by excavation and realignment in order to increase their capacity and reduce the frequency of out-of-bank flow. All channels on which improvement work is done will have, as a minimum, a designed within-bank capacity equal to the discharge to be expected once in five years.

The method used in making the necessary designs and evaluations is illustrated by the calculation for Reach 1 on sample stream I-92 in the Swatara Creek Watershed.

By field surveys it was determined that the hydraulic slope at bank full stage was 0.0064; the roughness coefficient $n = 0.045$ and the cross section area of the present channel approximately 12 square feet. Using Manning's formula, the velocity was calculated at 3 feet per second. Using the formula $Q = AV$, the bank full discharge under present conditions was calculated to be 36 cfs or, for the 3.45 square mile drainage area, 10.4 csm. The discharge-frequency relationship for Swatara Creek (see Section III) indicates this discharge has a 200 percent chance of occurrence in any one year. Because of frequent flooding, the 179 acres of adjacent fertile bottomland, is used only for pasture and is classified "poor pasture".

It has been established that to permit pasture improvement and management for good pasture production the frequency of flooding should not be greater than once in five years. Using the discharge-frequency relationships for Swatara Creek, it was determined that a

discharge equal to 111 csm, or 383 cfs, would have a 20 percent chance of occurrence. Using Manning's formula, with S = 0.0064 and an improved roughness coefficient n = 0.035, it was determined by trial that a new channel section 3.2 feet deep, with a 14 foot bottom width and 2 to 1 side slopes, would have the necessary discharge capacity, at bank-full stage, of 387 cfs.

These same determinations and calculations are made at frequent sections along the reach to indicate the required channel size at each section. In each case the channel is designed to carry a discharge, with a 20 percent chance of occurrence.

The estimated installation cost of this channel improvement includes $5,198 for clearing and excavation, $970 for rights-of-way, $925 for engineering and supervision, and $925 for contingencies, making a total installation cost of $8,018. Of this total, $5,517 is considered a public cost and $2,501 a private cost. Using interest rates of 2½ percent and 4 percent respectively for public and private expenditures, the annual equivalent of installation cost is $238. The annual maintenance cost is estimated at $352, which gives a total annual cost of $590. By calculating the enhancement value accruing to the 179 acres of bottomland, the annual benefit is determined to be $1,164 and the benefit-cost ratio is approximately 2 to 1.

Using the above methods, the average annual benefit from the recommended stream channel work is estimated to be $47,667. Of this

amount, $43,944 is attributable to land enhancement on 5,982 acres, while the remaining $3,723 is due to flood damage reductions. The latter value is included in the flood reduction benefits shown in Table 1.

Summary of Benefits from Additional Measures. The total average annual benefit from the recommended additional measures amounts to $50,780. Of this amount $43,944 is from land enhancement and $6,836 from reduction in inundation damage.

OTHER BENEFITS FROM RECOMMENDED LAND TREATMENT PROGRAM

In addition to the benefits already discussed, there will be other benefits which will largely accrue to individual owners and operators of land in the watershed. Land treatment measures in the recommended program not only reduce soil erosion and retard runoff but also increase crop production. Changes in land use recommended may reduce farm operating costs on land that is retired to less intensive uses.

Increased Income from Crops.

Appraisal Method. Contour farming practices, and other conservation practices recommended for rotation cropland will increase yields about 10 percent. This increase was applied to the present yield of the land to remain in cropland. This land produces higher yields than the average of all present cropland, so the total increase over present yields reflects both the effect of conservation practices and the conversion of the low yielding cropland to other uses. No increase in yields of orchards was claimed

for conservation practices. Thus, the spread between present and future orchard yields represents the difference in yield of the land to remain in orchard and the average yield of all land now in orchards. The increase in average crop yields more than offsets the effect of reducing cropland acreage in all cases except oats, miscellaneous small grains, peaches and apples. The reduction in these crops appear to be consistent with farmers' desires as indicated by an analysis of conservation farm plans now in effect. In the case of oats and miscellaneous small grains, the desired reduction in acreage is due to the low income from these crops. As to peaches and apples, the desired reduction in acreage is due to labor shortage and high risk.

Effect of Program. The change in acreage of individual crops, average per acre yields, and total production is shown in Table 4. The total value of production on cropland will be increased 3.8 percent, amounting to $2,399,373 annually. Sixty percent of the cropland measures from which this benefit arises will be installed under the recommended program. This gives a benefit on cropland creditable to the recommended program of $1,439,624 annually.

The acreage of perennial hay will be increased about 6.8 times or 64,100 acres which, together with the increases in hay production on cropland, will increase total hay production 27 percent. Inasmuch as the watershed is favorably located with respect to milk markets, the increased hay production can be efficiently utilized. About 48

288148
38900
249248

12 387 623 — before
12,275,105 — after
288,148a

Table 4. Change in Cropland Acreage, Present and Future Average Yields, and Change in Total Production on Cropland
Lower Susquehanna River Watershed

Crop	Change in Acreage		Average Per Acre Yields		Change in Production	
			Present	Future		
	(acres)	(percent)	(units)	(units)	(units)	(percent)
Corn	-38,900	-13.5	42.6 bu.	49.7	+ 105,790	+ 0.8
Potatoes	- 2,000	- 8.1	133.0 bu.	155.0	+ 235,600	+ 7.0
Tobacco	-	-	1,409.0 lb.	1,643.0	+7,090,200	+16.6
Miscellaneous Row Crops	- 1,100	- 3.8	149 $/ac.	174.0	+ 523,600	+12.3
Wheat	-12,300	- 4.9	22.6 bu.	26.4	+ 623,760	+11.1
Oats	-18,800	-29.6	29.6 bu.	34.5	- 336,960	-17.9
Barley	- 2,400	- 5.7	31.3 bu.	36.5	+ 131,840	+10.0
Miscellaneous Grains	- 4,500	-35.2	37 $/ac.	43.0	- 116,700	-24.6
Rotation Hay	-37,300	-12.3	1.39 ton	1.62	+ 9,241	+ 2.2
Peaches	- 1,500	-19.7	116.0 bu.	123.0	- 131,300	-14.9
Apples	- 5,000	-16.4	121.0 bu.	128.0	- 426,500	-11.6

VI

percent of the increased acreage of perennial hay needed, or 30,800 acres, will be installed under the recommended program. The value of production from this acreage amounts to $1,002,540 annually which is creditable to the recommended program.

The total average annual increased crop production benefit of the recommended program is $2,442,164, ($1,439,624 plus $1,002,541).1/

Increased Pasture Production

Appraisal Method. Pasture management as recommended will increase the grazing capacity 34 animal unit pasture days per acre. The value of an animal unit pasture day is based on hay equivalents grazed daily by an animal unit receiving no other feed, and 1/2 the market price of hay. The calculation is presented below:

35# hay equivalent grazed daily

$18.60 market price per ton of hay

$$\frac{18.60}{2 \times 2000} \times 35 = 0.16$$

$0.16 value of an animal unit pasture day

Effect of Program. Under the recommended program pasture management measures would be carried out on 109,600 acres. Watershed needs for pasture seeding, liming, and fertilization will be accomplished under present going programs. Based on the values

1/ Prices Used: Corn $1.45/bushel, potatoes $1.10/bushel, wheat $1.52/bushel, oats $0.78/bushel, barley $1.03/bushel, peaches $2.05/bushel, apples $1.65/bushel, hay $18.60/ton.

computed above the annual benefit from pasture management creditable to the recommended program is $596,224.

INCREASED FOREST PRODUCTION

Appraisal method. Data used in evaluating the forest land benefits were collected from several sources. Field parties gathered basic information on forest areas, timber types, forest condition classes, and forest ownership. Forest surveys and other studies carried on within and adjacent to the watershed provided data on growth rates, annual cuts, and stumpage prices. These surveys indicated that the watershed had an average growing stock of about 750 cu. ft. per acre, that the net growth rate was about 4% or an average of 30 cubic feet per acre per year, and that the present annual cut was about 20 cu. ft. per acre or 10 cubic feet less than net growth.

Data collected by the field surveys and studies provided a basis for computing the value of the estimated forest yield 70 years hence under the following conditions: (1) with the recommended program installed and effective, and (2) without the recommended program but assuming that current programs would continue at present levels. The estimated benefit was determined by subtracting the value of the forest yield expected without the program from the value of the forest yield expected with the program. An increase in quantity as well as an improvement in quality of timber products will result from installation

of the recommended program.

The following assumptions were made in computing the value of the future yield: (1) present annual cut will gradually increase until it equals annual net growth; (2) the present excess of growth over annual cut will accumulate as an addition to growing stock; (3) growth rate will remain constant at 4% while growth in cubic feet per acre will increase as growing stock volume is built up; (4) stumpage prices received by land owners will remain at the same levels; and (5) annual cut at 70 years will equal annual net growth at that time.

Present growing stock is expected to increase to approximately 825 cubic feet per acre within the next 12 years without the recommended program. This volume of growing stock will support an average cut of 33 cubic feet per acre per year indefinitely. Installation of the recommended program is expected to increase growing stock volume to approximately 1,200 cubic feet per acre in the next 70 years. This is sufficient growing stock volume to support an annual cut of between 47 and 48 cubic feet per acre per year.

The value of the yield under both conditions was determined by: (1) computing total cubic foot volume of yield by multiplying yield per acre by the forest acreage, (2) allocating total cubic foot volume of yield to local products in accordance with expected distribution, (3) application of converting factors to cubic foot volumes allocated to specific products to determine number of units of such products to be sold, and (4) applying local stumpage prices (long

range) to number of units of each product to be sold.

Effect of Program. A comparison of the value of the expected yield 70 years hence with and without the recommended program is shown in table 5. The estimated future annual benefit from installation of the recommended program is $692,120.

SAVINGS IN CROP PRODUCTION COSTS

Appraisal Method. The program includes a reduction of 123,800 acres (11.5 percent) in total cropland. Inasmuch as the recommended program does not entail increased expenditures for seed, fertilizer or lime on cropland, there will be considerable savings in total growing costs.

The per acre production cost on the cropland converted to other uses is considerably lower than the average due to its low economic capacity and the tendency of operators of such land to make low expenditures for fertilizer, lime, seed and other physical inputs. This factor was taken into account in estimating the savings.1/ The total savings in production costs on cropland is partially offset by the cost of harvesting, storing and selling the increased production resulting from the program. 2/

1/ Growing costs per acre on land converted to other uses: Corn $14.57, potatoes $54.27, wheat $13.64, oats $12.05, barley $12.05, hay $2.99.

2/ Unit costs of harvesting, storing and selling: Corn $0.31/bu., potatoes $0.35/bu., tobacco $0.88/cwt., wheat $0.44/bu., oats $0.30/bu., barley $0.30/bu., hay $10.37/ton.

Table 5. Comparison of Expected Future Value of Timber Yields
With and Without Recommended Program
Lower Susquehanna River Watershed

Product	Percent of Annual Yield Used in Specified Products	Cubic Foot Volume Used in Specified Products	Converting Factor, Cubic Feet to Specified Product	Volume Sold in Specified Products by Common Unit of Measurement	Stumpage Prices By Common Unit of Measurement	Value of Stumpage Sold By Landowner
		Value of Yield With Recommended Program			(dollars)	(dol.)
Sawlogs	40	13,576,000	175	77,577 M	10.50 per M	814,560
Fuel Wood	5	1,697,000	65	26,108 Cords	.45 per Cord	11,750
Veneer Logs	5	1,697,000	175	9,697 M	17.50 per M	169,700
Posts	5	1,697,000	1	1,697,000 Posts	.03 Each	50,910
Cooperage	5	1,697,000	175	9,697 M	17.50 per M	169,700
Pulpwood	20	6,788,000	80	84,850 Cords	1.75 per Cord	148,490
Mine Timbers	15	5,091,000	80	63,637 Cords	2.65 per Cord	168,640
Other	5	1,697,000	175	9,697 M	10.50 per M	101,820
TOTAL		33,940,000				1,635,570
		Value of Yield Without Recommended Program				
Sawlogs	43	9,624,690	175	54,998 M	10.50 per M	577,480
Fuel Wood	8	1,790,640	65	27,548 Cords	.45 per Cord	12,400
Veneer Logs	1	223,830	175	1,279 M	17.50 per M	22,380
Posts	2	447,660	1	447,660 Posts	.03 Each	13,430
Cooperage	-	-	175	-	17.50 per M	-
Pulpwood	14	3,133,620	80	39,170 Cords	1.75 per Cord	68,550
Mine Timbers	30	6,714,900	80	83,936 Cords	2.65 per Cord	222,430
Other	2	447,600	175	2,558 M	10.50 per M	26,860
TOTAL		22,383,000				943,450
				Benefit from Recommended Program		692,120

VI

<u>Effect of Program.</u> The net effect of decreased total growing costs and increased harvesting, storing and selling costs, amounts to a savings of $905,863 annually. Of this amount, about 60 percent or $543,518 is creditable to the recommended program. The above figure does not include the cost of growing perennial hay inasmuch as this cost is included in the installation and annual operation and maintenance costs in tables 11 and 12.

OTHER BENEFITS NOT EVALUATED

<u>Benefits Resulting from Increased Production of Crop, Pasture, and Forest Products.</u> Inasmuch as increased production of feed crops was evaluated by applying the market price of feed grains to the increased production, additional benefit will accrue to farmers through the returns from the increased livestock numbers that can be supported by the increased feed. In addition, the increased production will reduce livestock production costs through providing more home grown feeds and the improved pastures will reduce hay and grain feeding during the pasture season. Also, not evaluated is the improved quality of roughages which will reduce expenditures for protein concentrates and reduce livestock losses due to dietary deficiencies.

The increased returns to processors and distributors, to be earned from handling the increased production of crops, livestock, and forest products resulting from the program, are not included in the benefits evaluated.

Other Benefits. Other benefits due to decreasing the hazards of floods and sedimentation, but not expressed in monetary terms, will occur from the recommended program. Such benefits will be the savings in lives and mental distress and the increase in property values. There will be benefits from increase in fish and wildlife, increased low water flow of streams resulting in pollution abatement, conservation of water, fewer interruptions in community functions, and other benefits that are more or less intangible.

SUMMARY OF MONETARY BENEFITS OF THE RECOMMENDED PROGRAM

The evaluated monetary benefits attributable to the recommended program are summarized in Table 6. These benefits are expected to be attained when the program reaches maximum effectiveness. It is estimated that openland measures will reach maximum effectiveness within five years after installation. While forest land measures will not become fully effective until 70 years after installation, 75 percent of these benefits will be attained 30 years after installation. The additional measures will be fully effective immediately following their installation.

COST OF THE RECOMMENDED PROGRAM

Costs of the recommended program account for all expenditures required to install, maintain, or operate the remedial measures. Materials and equipment supplied by landowners or operators and unpaid family labor are included as program costs. Maintenance

Table 6. Estimated Average Annual Monetary Benefit
From the Recommended Program
Lower Susquehanna River Watershed

Type of Benefit	Average Annual Benefit	
	(dollars)	
Reduction in Damage Due to Inundation		
Agricultural	3,955	
Non-Agricultural	35,349	
Subtotal		39,304
Reduction in Damage Due to Sediment		
Channel Sedimentation	12,312	
Highway Sedimentation	30,060	
Water Supply Pollution	4,950	
Reservoir Sedimentation	8,204	
Subtotal		55,526
Reduction in Damage Due to Erosion		2,031,900
Land Enhancement		43,944
Other Benefits 1/		
Increased Crop Production	2,442,164	
Increased Pasture Production	596,224	
Increased Woodland Production	692,120	
Savings in Production Costs	543,518	
Subtotal		4,274,026
TOTAL		6,444,700

1/ Benefits which accrue to the owners and operators of the land on which the recommended program is installed.

and operation of the measures are computed in terms of annual costs.

LAND TREATMENT MEASURES AND PRACTICES

Computation Method. Costs of specific measures were determined by applying unit costs of the measures to the number of units to be installed in the watershed. The unit costs of measures were determined by application of projected long-term prices of labor, equipment, and materials to the average quantity and type of each required. The prices and costs used for the individual items are shown in Table 7. Soil Conservation Service and Forest Service records of operations were used in determining quantity and types of labor equipment, and materials required. Supplementary data were obtained from other federal, state, and local agencies.

Educational costs are based on an estimate made from information supplied by the Extension Service of Pennsylvania and Maryland.

The installation costs of the individual measures include the cost of educational assistance, technical services, and administration of direct aids. These costs were computed separately and then combined with costs of labor, equipment, and materials for the individual measures.

Table 7. Prices Used in Computing Costs
Lower Susquehanna River Watershed

Item	Unit	Dollars Per Unit
Farm Labor	Hour	.72
Farm Tractor and Operator	Hour	2.15
Farm Truck and Operator	Hour	2.58
45 H.P. Tractor and Operator	Hour	6.68
Motorized Grader and Operator	Hour	7.21
Stoneboat	Hour	.45
Fertilizer (Hay)	Pound	.017
Lime	Ton	4.64
Fence Post	Each	.95
Barbed Wire	Rod	.31
Mulch	Ton	25.80
Hay Seed	Pound	.46
Tree Seedlings	M	8.50
Concrete (formed)	Yard	97.90

Cost Distribution.

The total installation cost of the land treatment practices and measures is $11,248,208. The distribution of this cost is shown in Table 8.

Table 8. Cost Distribution
Land Treatment Practices and Measures
Lower Susquehanna River Watershed

	Federal	Other Public	Private	Total
Land Treatment				
Installation	3,749,863 1/	220,012	4,430,509	8,400,384
Administration of Direct Aids	330,935			330,935
Technical Services	1,678,867	130,022		1,808,889
Educational Assistance	354,000	354,000		708,000
TOTAL	6,113,665	704,034	4,430,509	11,248,208

1/ Includes incentive payments, materials and special equipment

The Federal Government will bear up to one-half the cost of technical services needed to carry out the recommended forest land program. State and other public agencies will bear the balance of this cost. The Federal Government will also pay 47.6 percent of the cost of planting trees on private land and 72.5 percent of the cost of fencing forest land from grazing. The percentages of Federal and other public costs shown above are in line with present expenditures for these measures under "going" programs.

The correction of unsatisfactory watershed conditions on logging roads and skid trails now in use or abandoned will be a Federal cost. The Federal Government will also bear the additional cost necessary to bring the standards of logging roads to be constructed during the installation period up to a level satisfactory for good watershed management. The immediate benefits from the road stabilization program will be to the general public in the form of lowered flood peaks and reduction of sedimentation. The benefits to the individual land owner will be relatively small and so long delayed as to be unattractive to private capital. For these reasons it is proper that the public should bear the cost.

The Federal Government will bear the cost of improved forest management on federally owned lands.

State and other public agencies will bear the costs of installing the above practices on state and other public lands and will bear about 23 percent of the cost of tree planting on private land.

Private interests will pay all the costs of cultural operations except technical services on private forest land not in farm ownership. Farmers will pay 27.5 percent of the cost of fencing farm forests, and 29.4 percent of the cost of planting forest trees.

The total cost of public acquisition of approximately 5,000 acres of critical watershed lands is based on an estimated average cost of $5.15 per acre. Public agencies will bear the cost of

acquisition and the cost of the necessary improvement and management measures. The cost to the Federal Government involves only the cost of locating and delineating such critical areas.

Maintenance and Operating Costs.

Maintenance and operation costs of the land treatment program were computed by applying unit costs of maintenance and operation to the quantities of the measures to be installed. The unit costs were developed in a manner similar to that used for installation costs. The maintenance and operation costs reflect the additional cost of farm operations.

The cost of annual maintenance is estimated at $1,113,856. It is expected that 1.3 percent of this will be borne by the Federal Government, 1.4 percent by state and local public agencies, and the balance of 97.3 percent by local landowners and operators.

ADDITIONAL MEASURES

Diking.

Estimated installation costs of approximately 1.7 miles of diking are as follows:

Table 9. Installation Cost of Diking
Lower Susquehanna River Watershed

Item	Federal Cost	Non-Federal Cost		Total Cost
		Public	Private	
	(dollars)	(dollars)	(dollars)	(dollars)
Construction Cost	10,663	9,731	307	20,701
Easements and Rights-of-Way, etc.	-	-	583	583
Engineering, Supervision, etc.	3,193	-	-	3,193
Contingency	1,639	1,506	48	3,193
TOTAL	15,495	11,237	938	27,670

The estimated average annual maintenance cost of this measure is $1,377. The life expectancy of the diking has been calculated and an amount is included for the reconstruction of individual items as they become inadequate or destroyed. It is expected that the total maintenance cost will be borne by local interests and will be administered by a local agency or agencies acceptable to the Secretary of Agriculture.

Stream Channel Improvement.

Estimated installation costs of approximately 104 miles of stream channel improvement with the necessary lateral drainage for prevention of damages associated with overflow and sedimentation are as follows:

Table 10. Installation Cost of Stream Channel Improvement
Lower Susquehanna River Watershed

Item	Federal Cost	Non-Federal Cost		Total Cost
		Public	Private	
	(dollars)	(dollars)	(dollars)	(dollars)
Construction Costs	98,144	10,854	118,445	227,443
Easements and Rights-of-Way, etc.	-	112	31,034	31,146
Engineering, Supervision, etc.	40,826	354	-	41,180
Contingency	17,368	1,860	22,166	41,394
TOTAL	156,338	13,180	171,645	341,163

The estimated average annual maintenance and operation cost of this measure is $15,236. It is expected that this will be borne by local interests and will be administered by a local agency or agencies acceptable to the Secretary of Agriculture. Included in the maintenance costs is the cost of the necessary inspections. The life expectancy of the improvements has been estimated, and an amount included for the reconstruction of individual items at the end of their estimated life.

The distribution of the installation and maintenance costs of the individual practices and measures is shown in tables 11 and 12.

Table 11. Quantities and Distribution of the Installation Costs of the Recommended Program
Lower Susquehanna River Watershed

Measure	Unit	Quantity	Installation Costs			
			Federal	Non-Federal Public 1/	Non-Federal Private	Total
			(dollars)	(dollars)	(dollars)	(dollars)
Land Treatment Measures						
1. Contour Strip Cropping	Acres	566,700	494,790	26,904	468,351	990,045
2. Diversions and Terraces	Miles	2,600	866,981	47,436	126,302	1,040,719
3. Establishing Perrennial Hay	Acres	30,800	601,182	32,922	835,524	1,469,628
4. Outlets and Waterways	Acres	2,300	452,879	24,780	82,064	559,723
5. Pasture Management	Acres	109,600	456,876	24,780	1,213,742	1,695,398
6. Contour Furrowing	Acres	6,000	73,710	3,894	18,480	96,084
7. Streambank Erosion Control	Miles	65	420,206	23,010	351,780	794,996
8. Erosion Control Structures	No.	6,900	1,648,290	90,270	1,025,202	2,763,762
9. Wildlife Area Development	Acres	35,400	507,971	47,436	154,285	709,692
10. Improved Forest Management	Acres	721,800	397,206	179,066	36,922	613,194
11. Forest Planting	Acres	26,900	191,074	180,304	117,857	489,235
12. Public Land Acquisition	Acres	5,000	2,500	23,232	--	25,732
Sub-Total I			6,113,665	704,034	4,430,509	11,248,208
Additional Measures						
1. Diking	Miles	1.7	15,495	11,237	938	27,670
2. Stream Channel Improvement	Miles	104.	156,338	13,180	171,645	341,163
Sub-Total II			171,833	24,417	172,583	368,833
TOTAL			6,285,498 2/	728,451 2/	4,603,092	11,617,041

1/ State and local governments, their departments and agencies .
2/ Includes technical service and educational assistance.

Table 12. Quantities and Distribution of Annual Operation and Maintenance Costs of the Recommended Program
Lower Susquehanna River Watershed

Measure	Unit	Quantity	Annual Operation and Maintenance Costs			
			Federal	Non-Federal Public 1/	Non-Federal Private	Total
			(dollars)	(dollars)	(dollars)	(dollars)
Land Treatment Measures						
1. Contour Strip Cropping	Acres	566,700			22,321	22,321
2. Diversions and Terraces	Miles	2,600			4,018	4,018
3. Establishing Perrennial Hay	Acres	30,800			423,085	423,085
4. Outlets and Waterways	Acres	2,300			29,486	29,486
5. Pasture Management	Acres	109,600			392,888	392,888
6. Contour Furrowing	Acres	6,000			14,340	14,340
7. Streambank Erosion Control	Miles	65			68,640	68,640
8. Erosion Control Structures	No.	6,900			14,904	14,904
9. Wildlife Area Development	Acres	33,000			66,412	66,412
10. Improved Forest Management	Acres	721,800	14,500	15,727	47,535	77,762
11. Forest Planting	Acres	26,900			-	-
12. Public Land Acquisition	Acres	5,000			-	-
Sub-Total I			14,500	15,727	1,083,629	1,113,856
Additional Measures						
1. Diking	Miles	1.7			1,377	1,377
2. Stream Channel Improvement	Miles	104.			15,236	15,236
Sub-Total II					16,613	16,613
TOTAL			14,500 2/	15,727	1,100,242	1,130,469

1/ State and local governments, their departments and agencies.
2/ Technical services, materials and labor.

COMPARISON OF BENEFITS AND COSTS OF THE RECOMMENDED PROGRAM

Benefits and costs were computed separately for the land treatment measures and practices and the additional measures. All benefits and costs of the recommended program were based on projected long-term prices as shown below:

U. S. Projected Long-Term Price Indexes

Construction Costs	424 (1913 = 100)
Wholesale Lumber Prices	250 (1926 = 100)
Prices and Rates Paid Farmers Including Interest, Taxes, and Wages	215 (1910-14 = 100)
Prices Received by Farmers, All Products	215 (1910-14 = 100)

To compare benefits with costs, all values were expressed in annual terms. In converting installation costs to annual values, $2\frac{1}{2}$ percent and 4 percent interest rates were used respectively for public and private expenditures. For those measures where a significant delay is expected between the time of the expenditure and the accrual of benefit, discounting was employed using interest rates cited above.

Land Treatment Measures.

In developing land treatment measures, the aim was to include only those measures whose benefits were in excess of costs. However, because of the interdependency of many individual measures it was necessary to compute benefits for groups of measures.

In determining the benefit-cost ratio, discounting was used in evaluating benefits. Openland program measures will be fully effective within five years after installation. Forest land measures will not

become fully effective until 70 years. However, 75 percent of the full reduction in flood damage accruing to forest land will be attained 30 years after installation with full benefit in 70 years. In the case of increased forest production about 50 percent of the maximum annual growth will be attained by the 40th year after installation and the full annual growth in the 70th year. In estimating the rate of benefit accrual from increased forest production, due allowance was made for the reservation of growing stock. This amount was sufficient to build up stand stocking to a level high enough to produce the indicated volume per acre at current growth rates. It is estimated that for the first 13 years there will be no increase in benefits, for the next 27 years the increase will be at the rate of $11,666., for the next 10 years the rate of increase will be $30,685., and for the next 20 years the increase will be at the rate of $3,482. The annual expenditure for timber marking will reach 75 percent of the maximum within 30 years and the full amount of the expenditure by the 70th year. This cost was discounted to convert to an average annual value.

Other operating and maintenance costs were not discounted. All discounted values are shown in Tables 13 and 14.

Additional Measures.

In determining the additional measures to be recommended, benefits and costs were computed for each specific measure, and only those measures with benefits in excess of costs were recommended.

Table 13. Derivation of Average Annual Equivalent Cost Values of Land Treatment Measures for Benefit/Cost Comparison Lower Susquehanna River Watershed

Item	Installation Cost		Annual Operations & Maintenance Cost	Total Average Annual Equivalent Cost
	Initial	Average Annual Equivalent 1/		
	(dollars)	(dollars)	(dollars)	(dollars)
Openland				
Federal	5,552,885	138,072	-	138,072
Other Public	321,432	8,036	-	8,036
Private	4,275,730	171,029	1,036,094	1,207,123
Subtotal	10,120,047	317,137	1,036,094	1,353,231
Woodland				
Timber Markings 2/				
Federal	-	-	5,904	5,904
Other Public	-	-	6,248	6,248
Private	-	-	12,655	12,655
Other Costs				
Federal	590,780	14,769	4,869	19,638
Other Public	382,602	9,565	5,534	15,099
Private	154,779	6,191	21,669	27,860
Subtotal	1,128,161	30,525	56,879	87,404
TOTAL	11,248,208	347,662	1,092,973	1,440,635

1/ Conversion Factor: Public Costs @ 2½% interest, private @ 4% interest.

2/ Discounted Values: Costs increasing uniformly for 30 years when 75% of maximum is reached and continuing to increase uniformly until the 70th year when the full annual expenditure is reached. Public costs were discounted at 2½% interest and private costs at 4% interest. The maximum annual costs are federal $9,631; other public $10,193; and private $25,866.

Table 14. Derivation of Average Annual Equivalent Benefit Values of Land Treatment Measures for Benefit/Cost Comparison
Lower Susquehanna River Watershed

Kind of Benefit	Maximum 1/ Average Annual Benefit	Discount Rate	Discounted Value of Average Annual Benefit
	(dollars)	(percent)	(dollars)
Reduction of Inundation Damage			
Openland	23,376	2½	22,263 2/
Woodland	9,092	2½	5,573 3/
Subtotal	32,468		27,836
Reduction of Sediment Damage			
Channel Sedimentation	12,312	2½	11,726 2/
Highway Sedimentation	30,060	2½	28,629 2/
Water Supply Pollution	4,950	2½	4,714 2/
Reservoir Sedimentation	8,204	2½	7,813 2/
Subtotal	55,526		52,882
Reduction of Erosion Damage	2,031,900	4	1,881,499 2/
Other Benefits			
Increased Crop Production	2,442,164	4	2,261,395 2/
Increased Pasture Production	596,224	4	552,091 2/
Increased Woodland Production	692,120	4	166,100 4/
Savings in Production Costs	543,518	4	503,287 2/
Subtotal	4,274,026		3,482,873
TOTAL	6,393,920		5,445,090

1/ Benefit accrual when program is fully effective.

2/ Benefit increasing uniformly, reaching the maximum in 5 years after installation.

3/ Benefits increasing uniformly, reaching 75% of maximum within 30 years and continuing to increase uniformly until the seventieth year when the maximum annual benefit is attained.

4/ Maximum annual benefit will be realized gradually over 70 years. For the first 13 years there will be an increase in benefits, for the next 27 years the annual rate of increase will be $11,666, for the next 10 years the annual rate of increase will be $30,685 and for the next 20 years the annual rate of increase will be $3,482.

The annual equivalents of costs and benefits, as well as the benefit-cost ratios are shown in Table 15 for those additional measures investigated and found to be justified. Annual equivalents of benefits and costs of the total quantities of additional measures recommended are shown in Table 16.

Benefit-Cost Ratios.

The ratio of benefits to costs for the recommended program is 3.74 to 1. The benefit-cost ratio for the land treatment measures is 3.78 to 1 and for the additional measures is 1.79 to 1. The average annual equivalents of benefits and costs used to calculate these ratios are shown in Table 17.

Table 15. Additional Measures - Annual Equivalent Cost and Benefit - Benefit-Cost Ratio
Lower Susquehanna River Watershed

Type of Measure and Location	Quantity in Lineal Feet	Annual Equivalent Costs (dollars)	Annual Equivalent Benefit (dollars)	Benefit-Cost Ratio
Stream Channel Improvement				
Conestoga Creek	6,042	2,453	3,159	1.29-1
Sample Watershed No., I-64 1/	250	5	6	1.20-1
No. I-73	50	19	62	3.26-1
No. I-92	17,613	637	1,411	2.22-1
No. I-249	4,567	142	173	1.22-1
No.III-306	8,240	445	549	1.23-1
No.III-319	700	161	245	1.52-1
No.III-344	3,700	248	536	2.16-1
No.III-352	5,700	136	316	2.32-1
No.III-390	3,430	156	325	2.08-1
Diking				
Conodoquinet Creek	250	101	106	1.05-1
South Branch Codorus Creek	125	50	69	1.38-1
Sample Watershed No.III-319 1/	700	161	245	1.52-1

1/ Data were expanded to representative area.

Table 16. Annual Equivalents of Costs and Benefits of the Two Groups of Additional Measures Lower Susquehanna River Watershed

Item	Channel Improvement		Diking	
	(dollars)		(dollars)	
Costs				
Installation:				
Federal	156,338		15,495	
Other Public	13,180		11,237	
Private	171,645		938	
Total	341,163		27,670	
Maintenance:				
Private (Total)	15,236		1,377	
Total Annual Equivalent Cost		26,340 1/		2,083 1/
Benefits				
Flood Damage Reduction	3,723		3,113	
Land Enhancement	43,944			
Total Annual Benefit		47,667		3,113
Benefit/Cost Ratio		1.81 to 1		1.49 to 1

1/ Sum of annual maintenance cost and annual equivalent value of installation cost. Public and private installation costs were converted to average annual equivalent values by using $2\frac{1}{2}$ percent and 4 percent interest rates respectively.

Table 17. Benefit-Cost Ratios of the Recommended Program
By Groups of Measures
Lower Susquehanna River Watershed

Type of Measure	Annual Benefit 1/	Annual Cost 1/	Benefit-Cost Ratio
	(dollars)	(dollars)	
Land Treatment	5,445,090	1,440,635	3.78 to 1
Additional Measures			
Channel Improvement	47,667	26,340	1.81 to 1
Diking	3,113	2,083	1.49 to 1
Subtotal	50,780	28,423	1.79 to 1
All Measures	5,495,870	1,469,058	3.74 to 1

1/ Discounted values.